NOV 16 1981

COMPARISON OF ALTERNATIVE MODES

HAMILTON-WENTWORTH

RAPID TRANSIT PROJECT

16-81192-I01

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SUMMARY

1. The Region of Hamilton-Wentworth Technical Advisory Committee selected the following alternative transit systems for comparison:

- o Intermediate Capacity Transit System (ICTS)
  - operating primarily on an elevated guideway (the proposed system)
  - operating as a subway
- o Canadian Light Rail Vehicle (CLRV)
  - operating on-street, within a semi-exclusive right-of-way
  - operating on-street, in mixed traffic
- o On-Street Bus Transit
  - fleet consisting entirely of conventional coaches
  - fleet consisting of conventional coaches, articulated buses and/or trolley buses
  - fleet consisting of conventional coaches operating on bus priority lanes during road peak hours.

2. The alternative systems were evaluated using representative alignments and the following criteria:

- o System Operations - performance criteria governed by the mode of operation of each of the alternative transit systems under consideration.
- o System Design - design criteria and technological characteristics likely to affect system operations in the Hamilton Mountain Corridor.
- o Implementation - criteria which describe the impacts of the alternative transit systems during the construction period and the long term impacts following implementation.

- o Urban Impacts - criteria which describe the impacts of the alternative transit systems on the urban structure.

- o Environmental Impacts - criteria which describe the environmental impacts generated by the respective transit systems.

- o Costs - cost data including capital, operational and maintenance costs.

3. The results of the evaluation are summarized as follows:

- o System Operations: both ICTS modes were assigned the highest overall performance ratings, with CLRV on a semi-exclusive R.O.W. second. The ICTS systems had the best ratings because they provided the shortest travel time and were independent of road traffic delays.

- o System Design: the rating was similar to that for system operations, with both ICTS modes rated highest, and CLRV on a semi-exclusive R.O.W. second. The ICTS systems had the best performance because they were reliable, comfortable and were convenient for passengers to board.

- o Implementation: the on-street bus systems with conventional coaches only, or with some articulated vehicles, were assigned the highest ratings. Trolley buses were second. The bus systems were given the highest rating because they had no construction impacts or land requirements and did not restrict property access.

- o Urban Impacts: the ICTS subway was judged to have the highest rating, followed by ICTS elevated. The ICTS subway system had the best performance because it had fewer visual impacts (it is underground) and supported planning policies.

- o Environmental Impacts: the best rating was assigned to ICTS elevated, followed by ICTS subway, then CLRV on a semi-exclusive R.O.W. The ICTS elevated system had the best rating for environmental impacts because it is quiet, energy efficient and causes no air pollution.

- o Cost: the bus systems (excluding trolley) had the lowest cost (combined capital, operating and maintenance), followed by trolley bus, ICTS elevated, CLRV (both modes have similar costs) and ICTS subway, in order of increasing cost.

The evaluation is presented in Table 6.2.

4. Overall, excluding cost, the two ICTS systems had comparable ratings, both considerably higher than the CLRV on semi-exclusive R.O.W. which ranked second and the CLRV in mixed traffic which ranked third.

5. In general, the bus systems do not satisfy the Official Plan policies concerning an improved rapid transit connection between the Mountain and downtown and are subject to deteriorating service in the long term as road traffic congestion and delays increase.

   According to the road capacity and travel demand forecast data presented in the Transportation Capital Facilities Plan, the travel demand across the escarpment in the Mountain corridor will exceed the capacity of the existing arterial road network by the late 1980's or early 1990's. One alternative, to reserve one existing lane on the Jolley Cut exclusively for transit during peak periods, would maintain reasonable bus travel speeds, but would reduce the capacity for all road traffic across the escarpment.

6. The total estimated system costs (expressed in millions of 1981 dollars) are:

	Capital Cost	Operating and Maintenance Cost	Total Cost
ICTS Elevated	135.0	123.5	258.5
ICTS Subway	254.0	126.5	380.5
CLRV S.E. R.O.W.	159.5	148.0	307.5
CLRV Mixed Traffic	160.5	147.5	308.0
Standard Coach	24.0	123.5	147.5
Articulated Bus	24.0	115.5	139.5
Trolley Bus	31.5	119.5	151.0
Priority Lanes	22.5	119.0	141.5

1. INTRODUCTION

The objective of this report is to compare the performance characteristics of the proposed Intermediate Capacity Transit System (ICTS), operating in an elevated mode, with other proven and available transit systems, also capable of operating in the Hamilton Mountain Corridor.

The study approach included the following activities:

- Identification of the alternative transit modes and respective system characteristics;
- Selection of a representative route alignment and mode of operation for each of the alternatives;
- Establishment of evaluation criteria and corresponding measures;
- Development of a strategy for evaluating the alternatives; and
- Comparison and evaluation of the alternatives.

The analysis is based on the population and travel projections provided by the Regional Municipality of Hamilton-Wentworth and on the work carried out to date by the Planning, Engineering and Environmental Assessment Teams as part of the Pre-Implementation Planning Program. The effects of recently revised population projections are being analyzed by the Region and are not available for this report.

The comparison of the alternative modes was confined to service between downtown and the Mountain. The capacity of each alternative mode was designed to be approximately the same to satisfy the projected travel demands.

System characteristics pertaining to ICTS and Canadian Light Rail Vehicles (CLRV) were provided by the Urban Transportation Development Corporation (UTDC), as were the respective capital, operating and maintenance costs. Similar costs for buses and trolleys operating in Hamilton were obtained from the Hamilton Street Railway (HSR) or from annual statistics published by the Canadian Urban Transit Association (CUTA).

Presented in this report are the findings of the investigation.

2. IDENTIFICATION OF ALTERNATIVE MODES

A review of candidate technologies for service between downtown and the Mountain led to the selection by the Region's Technical Committee of the following alternative transit systems which were identified for analysis:

- o Intermediate Capacity Transit System (ICTS)
  - operating primarily on an elevated guideway (the proposed system)
  - operating as a subway
- o Canadian Light Rail Vehicle (CLRV)
  - operating on-street, within a semi-exclusive right-of-way
  - operating on-street, in mixed traffic
- o On-Street Bus Transit
  - fleet consisting entirely of conventional coaches
  - fleet consisting of conventional coaches, articulated buses and/or trolley buses
  - fleet consisting of conventional coaches operating on bus priority lanes during road peak hours.

The Technical Committee considered these alternatives most appropriate for analysis as representative of the transit options available to the Region. Articulated streetcars were not selected for analysis by the Committee. The CLRV was considered to be representative of Light Rail Transit (LRT) technology. Higher capacity alternatives such as a heavy rail transit system similar to the Toronto subway were not considered to be warranted in the Mountain Corridor.

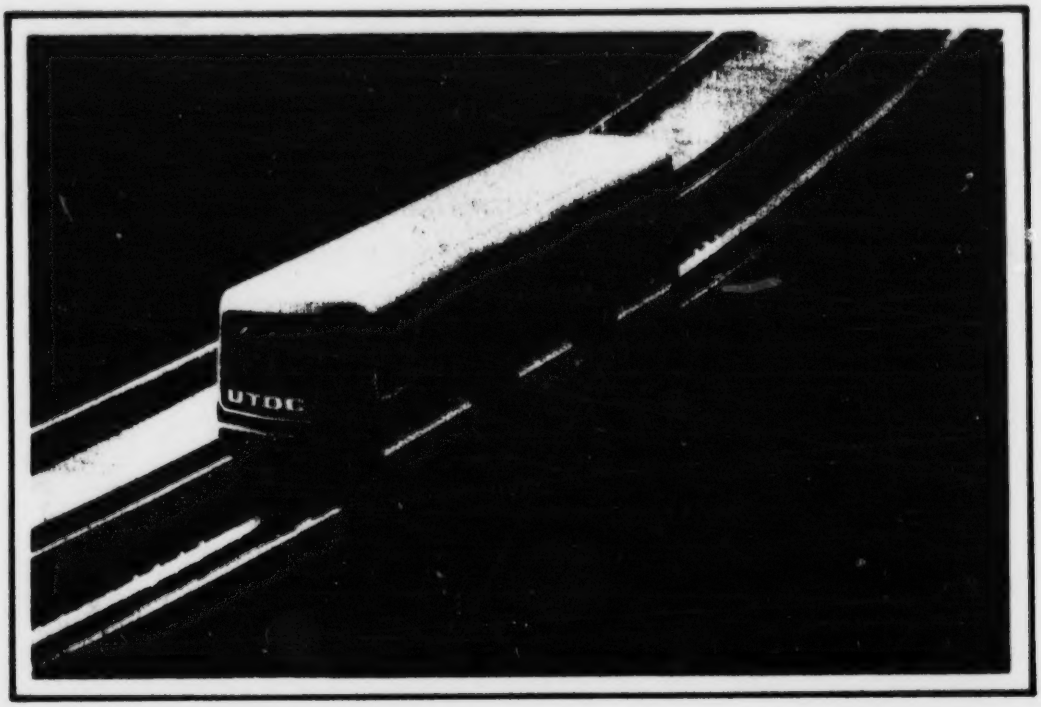
This report is intended to compare generic alternative transit modes rather than the alternative technologies available for each mode.

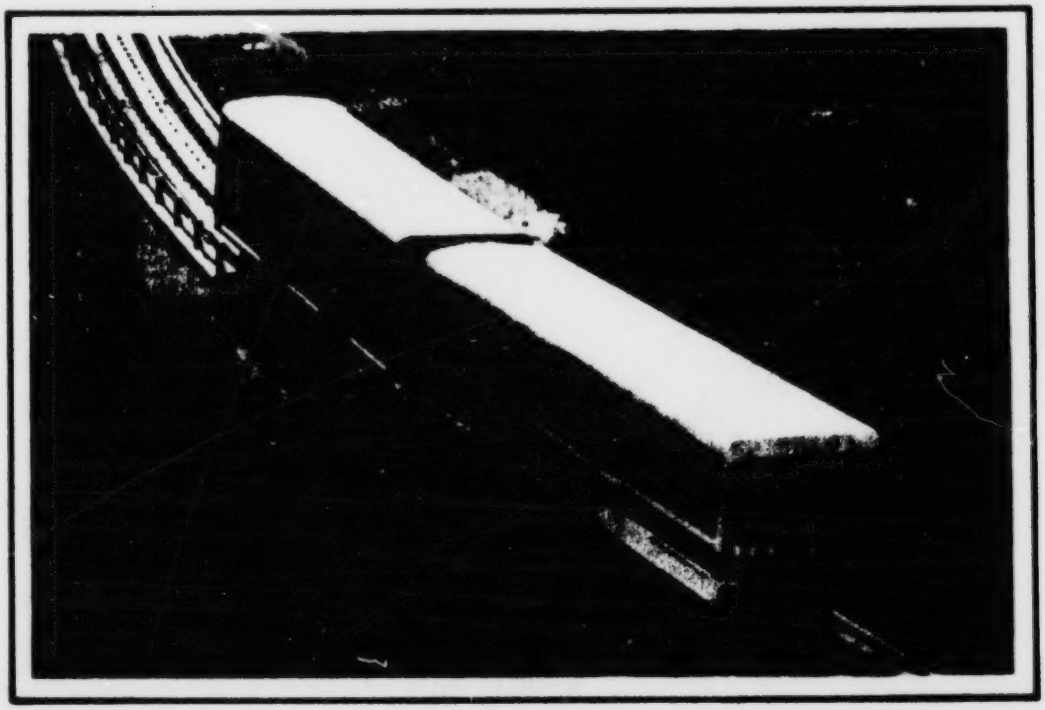
Improvements to the existing bus system were selected for comparison by the Technical Committee, although they will not promote increased transit use to the extent desired in the Official Plan policies concerning an improved rapid transit connection between downtown and the Mountain. The Regional Official Plan states (Section 9.3.3.[b]): "The sub-regional centre on the Hamilton Mountain be a focal point for transit service above the escarpment in Hamilton and Stoney Creek, with a major high speed transit connection between this centre and downtown Hamilton".

Furthermore, Section 9.3.8 states that "a transit system with increased transit capacity receive a high priority in transportation planning in the urban areas of the Region, especially in the corridor connecting downtown Hamilton to the sub-regional centre on the Hamilton Mountain".

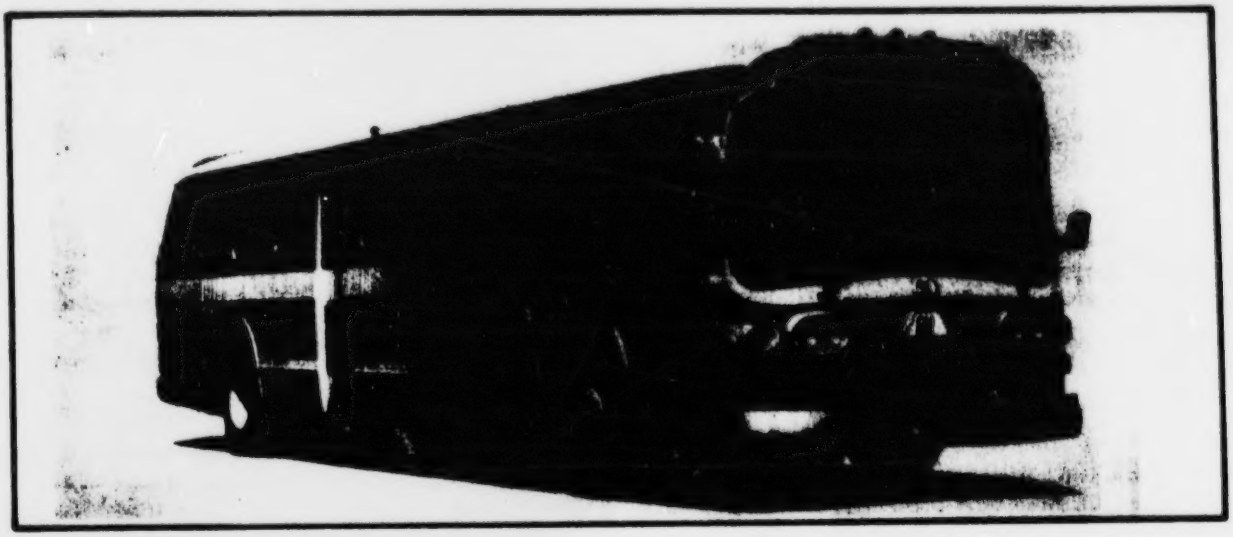
The City of Hamilton Draft Official Plan also emphasizes this point: "To minimize the need for new road facilities in congested corridors and to accommodate large volumes of transit users, Council may consider the potential of a new and innovative intermediate capacity transit line connecting downtown Hamilton to an appropriate location on the Mountain (Section 3.2.11)."

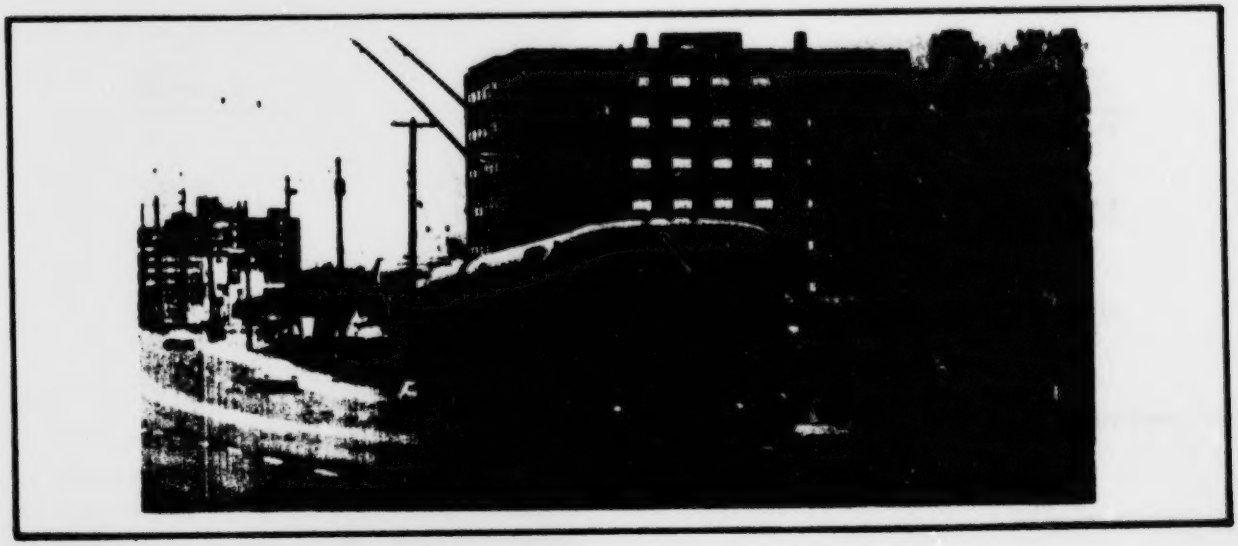
Illustrations of the transit alternatives are presented on the following pages. Presented in Table 2.1 are the characteristics unique to each of the systems.





INTERMEDIATE CAPACITY TRANSIT SYSTEM (ICTS)





- Conventional Coach
- Articulated Vehicle

Table 2.1
Generic System Characteristics

Characteristic	Units	Transit System: ICTS (Elevated & Subway)	CLRV (S.E. R.O.W. & Mixed Traffic)	Bus Transit: Standard Coach	Bus Transit: Articulated Vehicle	Bus Transit: Trolley Bus
1. Vehicle Specifications						
1.1 Dimensions						
Length	m	12.7	15.4	12.2	18.3	12.2
Width	m	2.5	2.6	2.6	2.6	2.6
Height (above track/pavement)	m	3.1	3.4	3.1	3.1	3.4
1.2 Weight						
Empty	t	13.0	23.0	9.5	15.0	9.5
Crush Load	t	21.0	32.0	17.0	26.0	17.0
1.3 Performance						
Maximum Speed	km/h	80	80(1)	90	90	70
Minimum Turning Radius	m	30.0(2)	30.0(2)	12.5	12.5	12.5
1.4 Capacity						
Seats	-	30	46-51	51-53	63	42
Design Load	passengers	75	90-95	65-80	120-140	65-80
Crush Load	passengers	108	125	100-120	160-180	100-120
1.5 Access						
Number of Doors	-	2 per side	2 on right	2 on right	3 on right	2 on right
Width of Doors	m	2.4	2.4	1.8	3.1	1.9
Number of Steps(3)	-	0	4	3	3	3
1.6 Control						
Driver Required	-	No	Yes	Yes	Yes	Yes
Attendant Required	-	No	No	No	No	No
1.7 Energy						
Type	-	Electrical 600 V-DC	Electrical 600 V-DC	Diesel(6 cyl) 179 HP	Diesel(8 cyl) 255 HP	Electrical 600 V-DC
Consumption	-	1.3 kw-h/ veh-km	1.05 kw-h/ veh-km	51.5 ℓ/ 100 km	81.0 ℓ/ 100 km	2.3 kw-h/ veh-km
	BTU/veh-km	4 450	3 600	18 100	28 500	7 850
1.8 Environment						
Noise Level at 20 m(4)	dBA	66	72	-	-	
Vibration - peak	dBA	60	80	N/A	N/A	N/A
- frequency of occurrence	Hz	50	65-80			
2. ROUTE/LINE SPECIFICATIONS						
2.1 Line						
Track Required	-	Yes	Yes	No	No	No
Power Distribution	-	Third Rail	Single Overhead Wire	Self Contained	Self Contined	Double Overhead Wire
2.2 Operations						
Units Per Train						
- Normal	-	2	1-2	N/A	N/A	N/A
- Maximum	-	6(5)	6	N/A	N/A	N/A
2.3 Life Expectancy						
Vehicles	years	30	25	15-18	15-18	15-18
Structures	years	50	25/50(6)	N/A	N/A	25(7)

Notes:

(1) Applies only within exclusive or semi-exclusive rights-of-way. In mixed traffic, speeds are governed by local conditions.

(2) Turning radius about centre line of vehicle operating at 25 km/h.

(3) Steps including landing.

(4) Single vehicles operating at approximately 50 to 55 km/h.

(5) One, two and three married pairs respectively.

(6) 25 years for electrical overhead, 50 years for tunnel.

(7) For electrical overhead system.

3. SYSTEMS DESCRIPTIONS

3.1 Route Alignments

A representative route alignment and mode of operation was assumed for each of the alternative transit systems. These representative alignments were selected from a transportation viewpoint for the purpose of comparing and evaluating transportation system alternatives. Although land uses and potential urban impacts were taken into consideration during the selection process, the proposed alignments, with the exception of the elevated ICTS, may not necessarily reflect all of the existing site constraints.

The routes chosen for each alternative transportation mode have been selected to follow a route similar to that chosen for the elevated Intermediate Capacity Transit System (ICTS), with some minor variations to minimize cost or to maximize operational considerations.

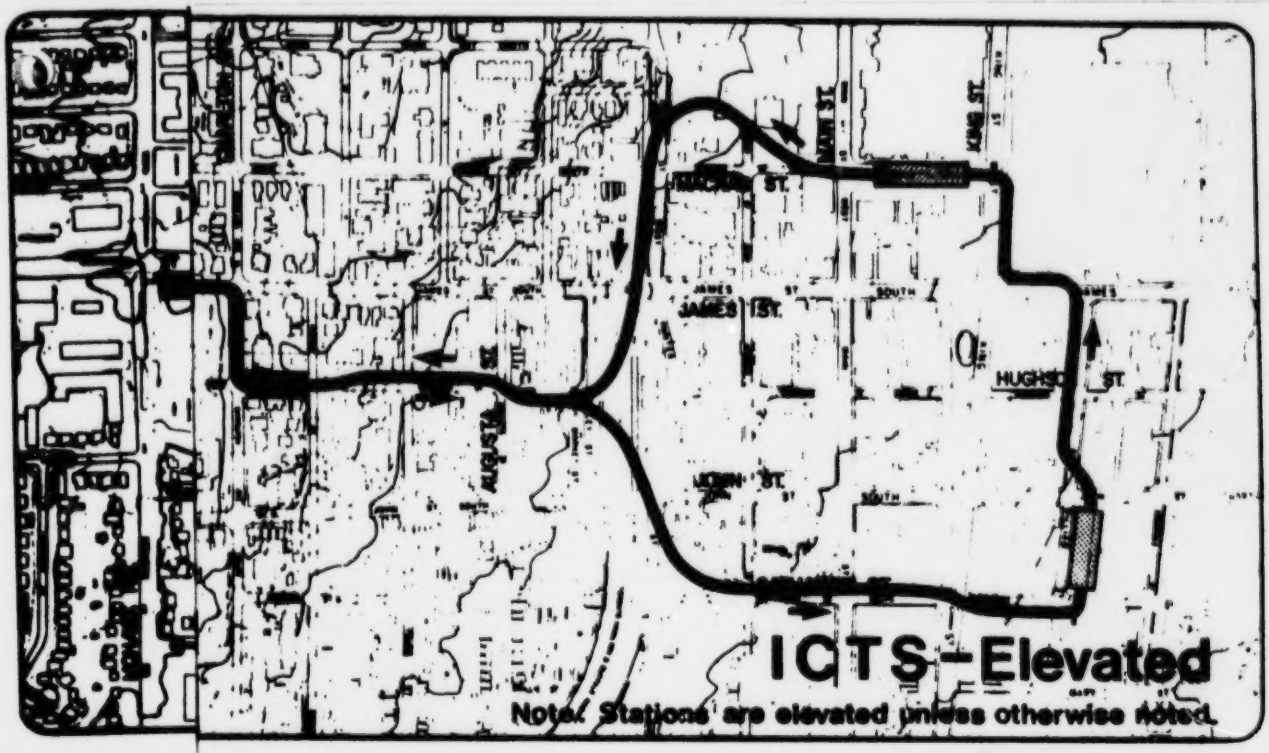
a) ICTS Subway

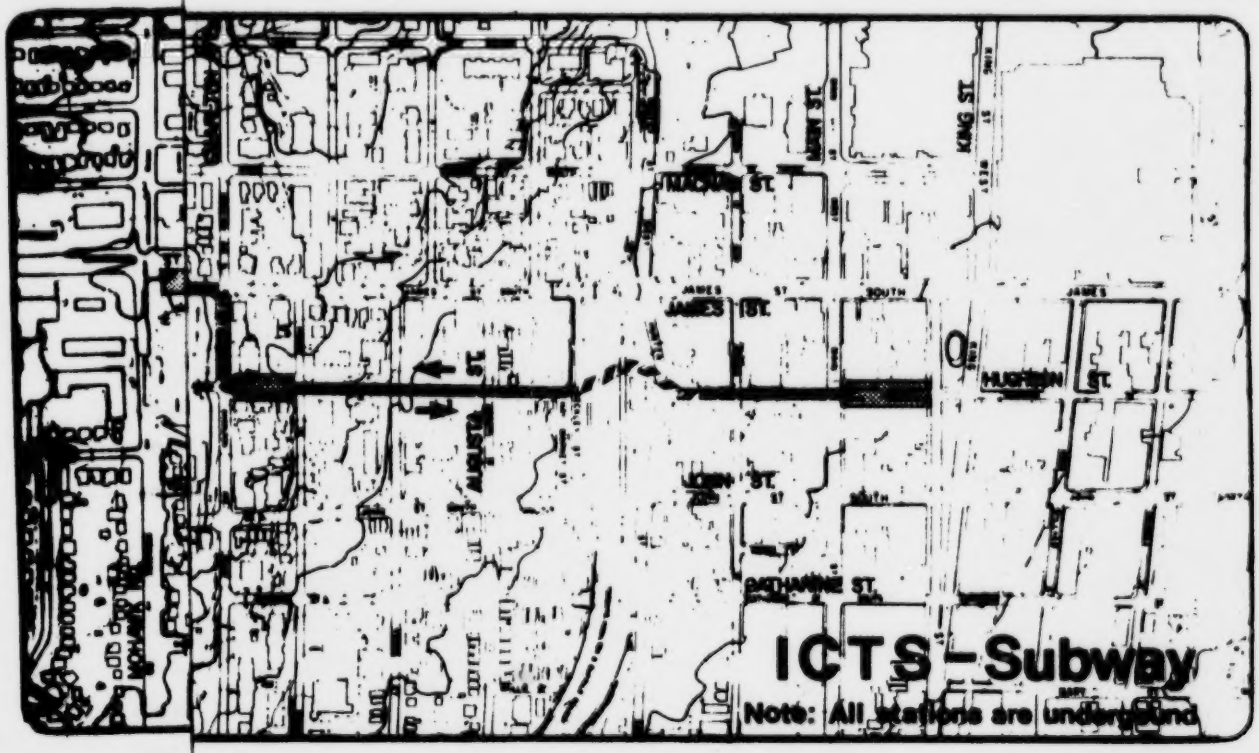
- Utilizes Hughson Street, rather than James Street directly to the downtown, to minimize traffic disruption and major utility relocations.

- Does not loop in the downtown and does not provide service to King/Catharine and King/MacNab, but terminates in Gore Park at King/Hughson due to the high cost penalty of a total underground loop service in the downtown.

b) CLRV

- Both CLRV options utilize a tunnel to cross the escarpment, to avoid a circuitous route over the escarpment, to avoid conflict with major arterial roads on the escarpment and to improve the overall operational elements of the CLRV system. A completely "exclusive" right-of-way for a CLRV was not available, without





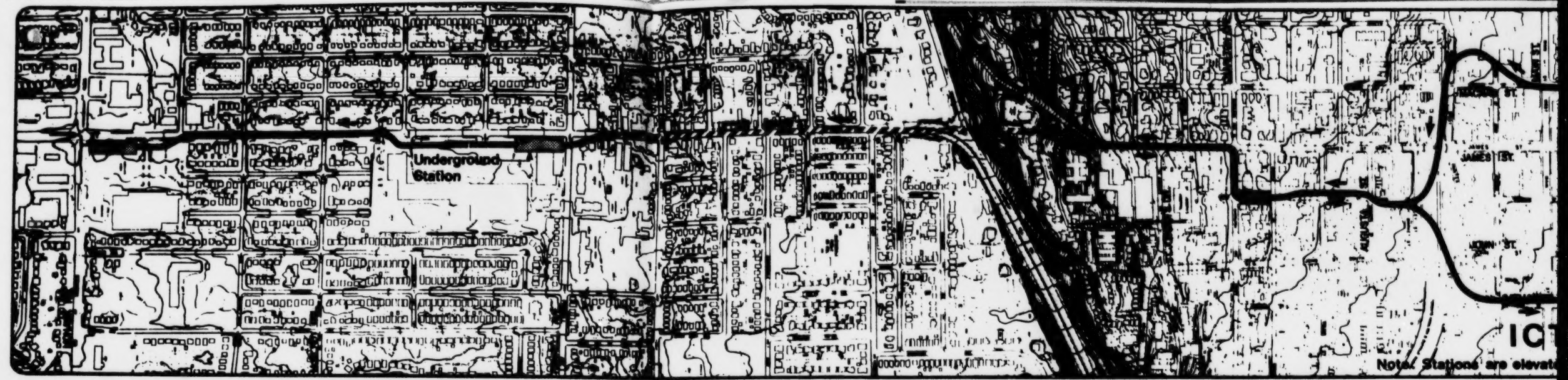
Legen

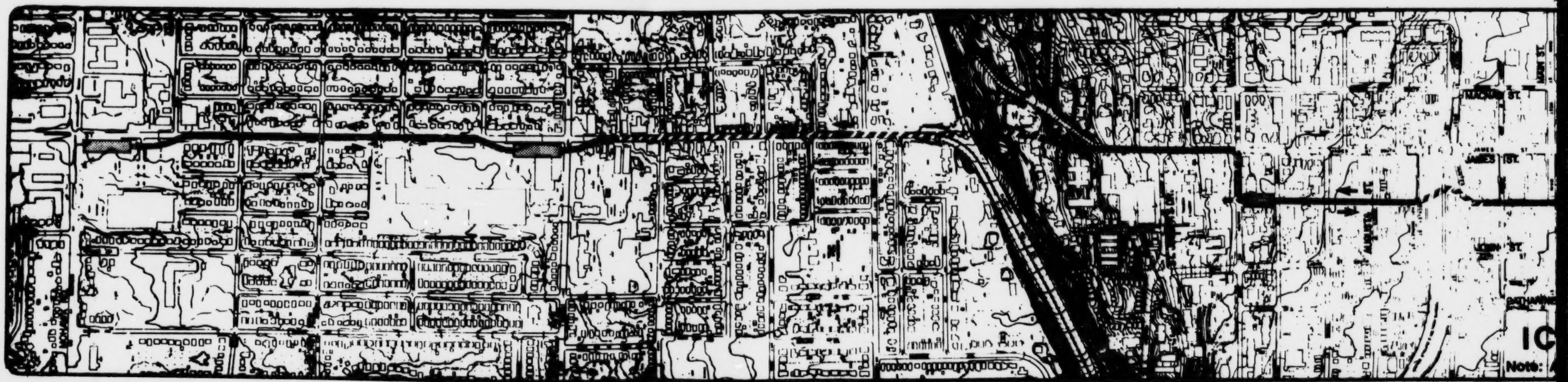
Proposed ICTS Routes

0 100 200 300 400 500

Scale In Metres

Figure 3.1





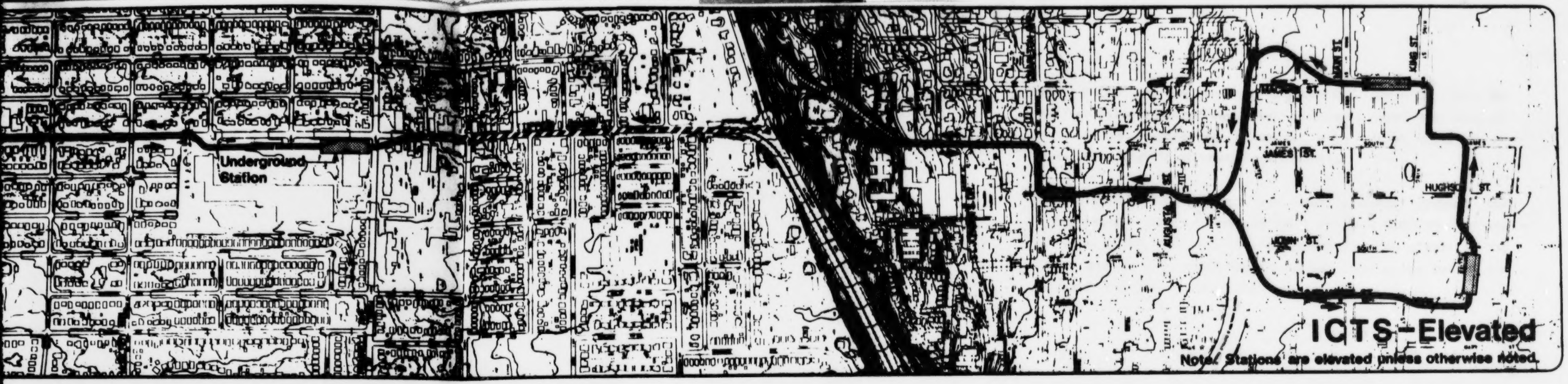
Legend

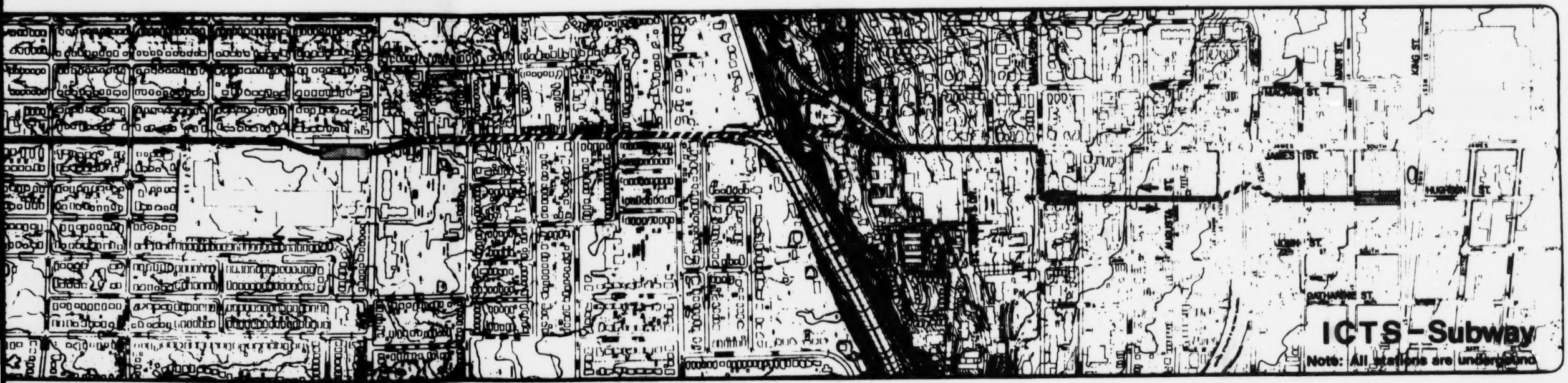
- Elevated Section
- Cut and Cover
- Tunnel
- At Grade
- Station
- Transit Terminal
- On Street Transit Platform
- Transit Stop
- Direction Of Service

Proposed IC

0 100 200 300 400

Scale In Metres





At Grade

Station

Transit Terminal

On Street Transit Platform

Transit Stop

Direction Of Service

Proposed ICTS Routes

0 100 200 300 400 500

Scale In Metres

Figure 3.1

major social and environmental disruptions. However, the CLRV semi-exclusive right-of-way takes advantage, where possible, of an exclusive right-of-way except at major street crossings or areas where traffic movements are essential.

The ICTS and CLRV systems all have a tunnel through the escarpment as a major feature of their routes. Detailed profiles for each system have not been developed, but the grades in the tunnel and on the tunnel approaches will differ to obtain the elevation required at the tunnel portal:

	Length of Grade		
Mode	4.83% Grade	5% Grade	7.88% Grade
ICTS Elevated	950 m	-	330 m
ICTS Subway	500 m	150 m	630 m
CLRV	630 m	150 m	500 m

In general, these grades do not present any operational problems and any effects upon travel time have been included in the appropriate calculations.

Presented in the following sections is a description of each of the assumed route alignments and assumed modes of operation including transit station/stop requirements, integration with feeder bus systems and fare collection procedures.

3.1.1 - ICTS - Elevated

The proposed route alignment, as shown in the Functional Plan Report, commences with an elevated station situated in the Miracle Mart parking lot at the north-east quadrant of the intersection of Mohawk Road and Upper James Street, (Figure 3.1). The station is oriented parallel to Upper James Street.

From the station the double elevated guideway proceeds north along the east side of Upper James Street to Richwill Road, then curves into a centre median on Upper James Street.

The line continues north along Upper James Street to Wembley Road where it curves out of the road allowance onto the site of the Mountain Plaza Mall.

Here, the line enters a transition from the elevated mode to a tunnel section. An underground station is located at the north end of the transition, immediately to the south of Fennell Avenue.

North of this station, the proposed route alignment curves to the west under Upper James Street and continues north as a cut-and-cover section extending to a point immediately north of Genesee Street. Here, the guideways separate and enter two independent tunnels descending at a grade of approximately five percent.

The line emerges from the escarpment as an elevated double guideway at a portal located in the right-of-way of the former Incline Railway.

The assumed line proceeds north along the centre of James Street, turns east along Charlton Avenue, then north along Hughson Street entering an elevated station located north of Charlton Avenue. There may be adjustments to the alignment and station location in the vicinity of St. Joseph's Hospital at the detailed design stage.

The line proceeds north along the west side of Hughson Street. At Augusta Street, the line crosses Hughson Street, swings to the rear of properties fronting onto the east side of Hughson Street and continues north to Haymarket Street where it connects to the CBD single guideway loop.

The downtown single guideway loop is a one-way line (possibly running counter-clockwise) about the downtown area.

The loop begins at Haymarket Street to the east of Hughson Street. A future station could be located near the TH&B railway station if GO train service is relocated there from the CNR station on James Street North to the TH&B station. This station would also serve this identified growth node.

The line proceeds north-east across the TH&B tracks and continues north along the west side of Catharine Street to King Street. Provision is made for a future station to be located on the west side of Catharine Street between Main Street and King Street.

At King Street, the line curves to the east side of Catharine Street and continues north then turns west onto the north side of King William Street.

An elevated station is located on the north side of King William Street between Catharine Street and John Street.

West of the station, the line curves to the south side of King William Street, proceeds west to James Street, then turns south along the west side of James Street to King Street.

At this point, the line turns west along the north side of King Street to MacNab Street, where it turns south and enters the main downtown station located over the centre median of MacNab Street.

South of the station, the line crosses Main Street, curves south-west from MacNab Street and proceeds along an alignment behind the library and Football Hall of Fame.

The line swings around the Whitehern Estate above the City Hall parking lot, crosses Hunter Street and the TH&B tracks and proceeds east along the south side of the TH&B tracks rejoining the double guideway near Hughson Street.

3.1.2 - ICTS - Subway

The assumed route alignment begins with an underground station situated in the Miracle Mart parking lot at the northeast quadrant of the intersection of Mohawk Road and Upper James Street (Figure 3.1).

North of the station, the line consisting of a double track, follows the east side of Upper James Street to Richwill Road then curves to the west and continues north under Upper James Street to Wembley Road.

At Wembley Road, the line curves out of the road allowance and continues north under the Mountain Plaza Mall parking lot to enter an underground station located south of Fennell Avenue.

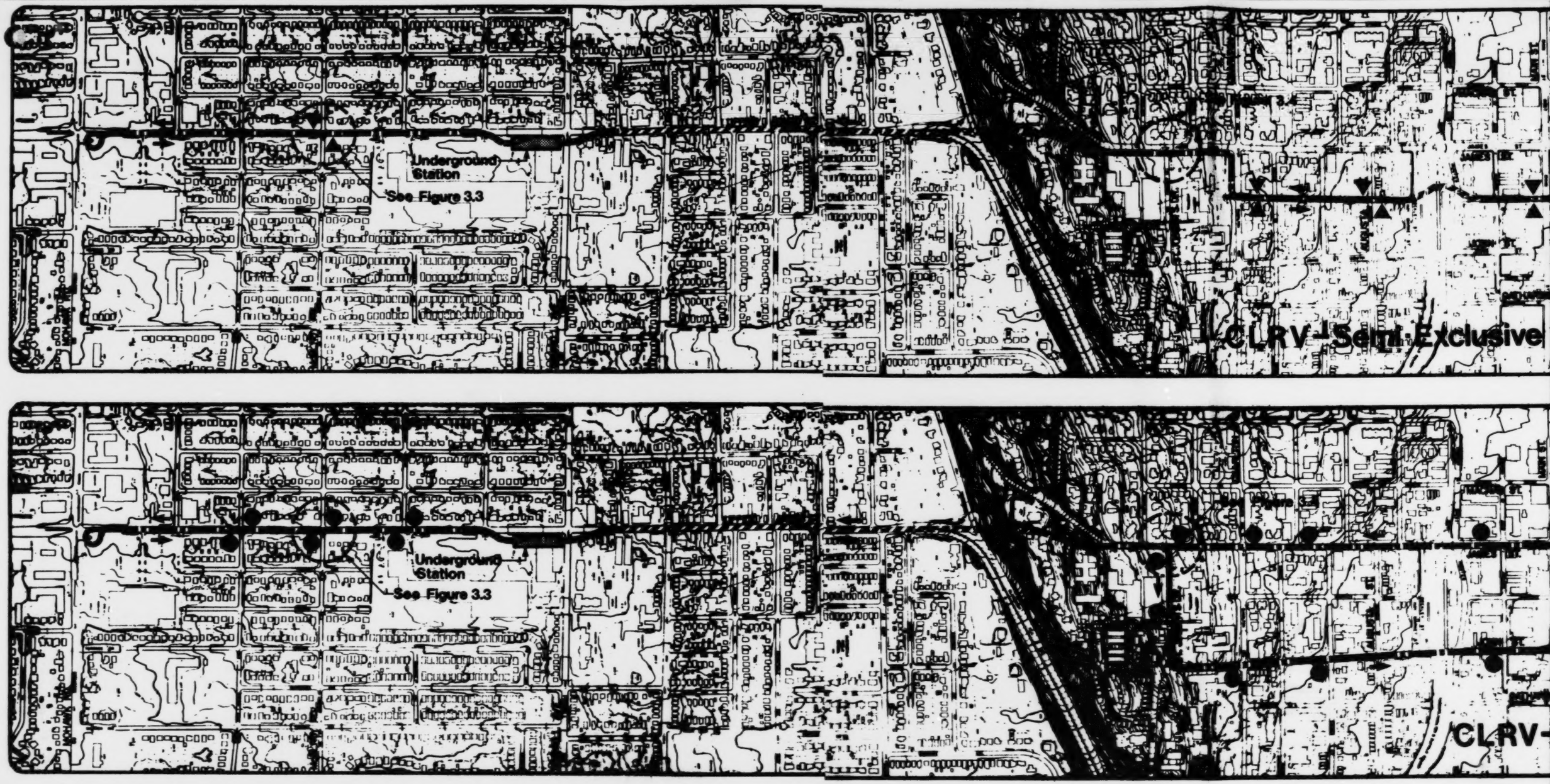
North of the station, the line curves back into the road allowance and continues north under Upper James Street.

North of Genesee Street, the line splits into two single directional tunnels and descends beneath the escarpment.

Emerging from the escarpment, the line continues north under James Street, turns west under Charlton Avenue and north under Hughson Street. An underground station is located in the vicinity of St. Joseph's Hospital.

The line continues north under Hughson Street looping under and to the west of the TH&B railway station and terminates in an underground station under Hughson Street between Main Street and Gore Park.

Most of the line is constructed using cut and cover techniques, with the exception of the section north of Genesee Street to the face of the escarpment, which consists of two one-way tunnels, where a tunnel boring machine would be used.



Legend

- Elevated Section
- Cut and Cover
- Tunnel
- At Grade
- Station
- Transit Terminal
- On Street Transit Platform
- Transit Stop
- Direction Of Service

Note

Boarding facilities are constructed at grade unless otherwise noted.

Proposed CL

0 100 200 300 400

Scale In Metres

Note

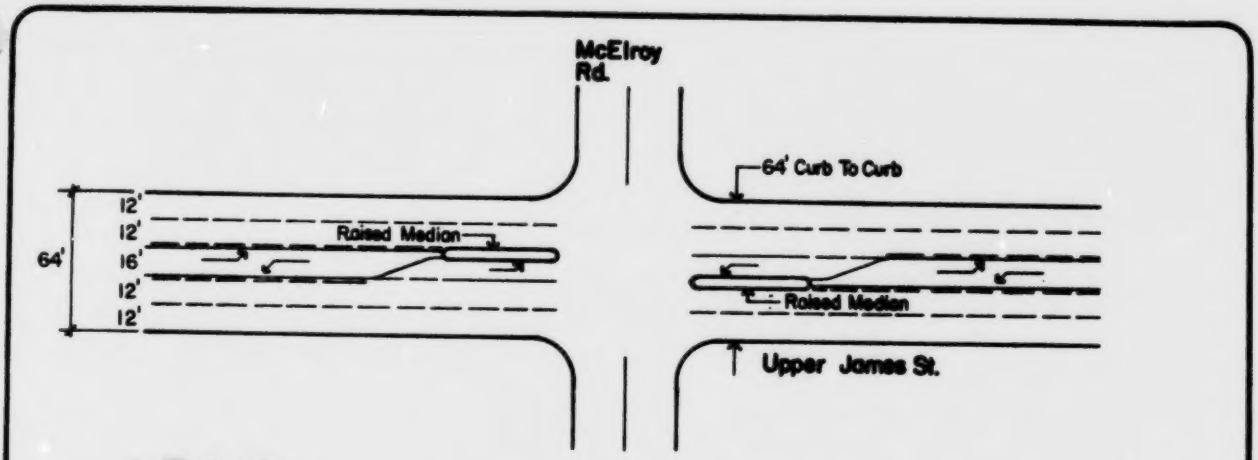
Boarding facilities are constructed at grade unless otherwise noted.

Proposed CLRV Routes

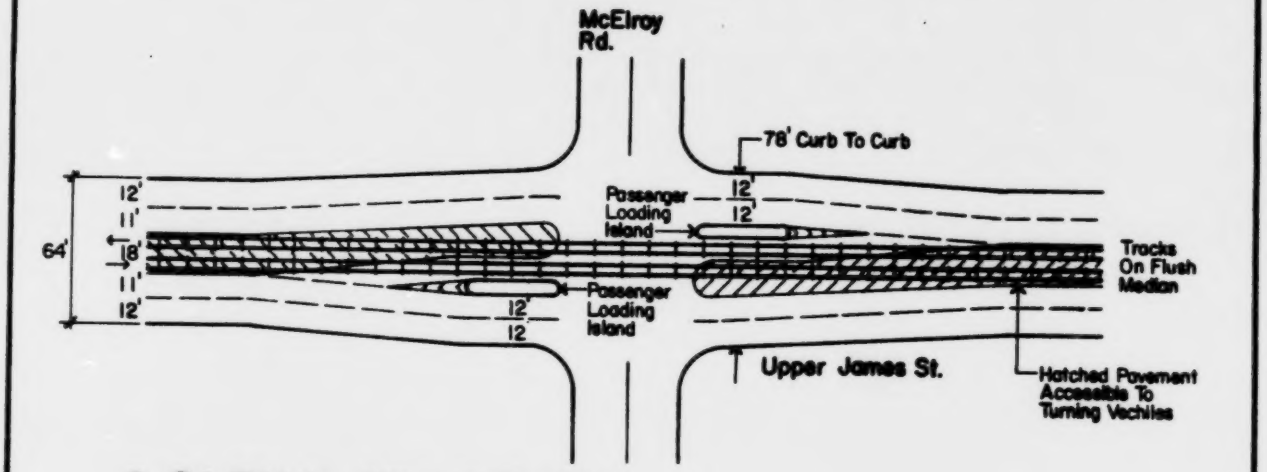
0 100 200 300 400 500

Scale In Metres

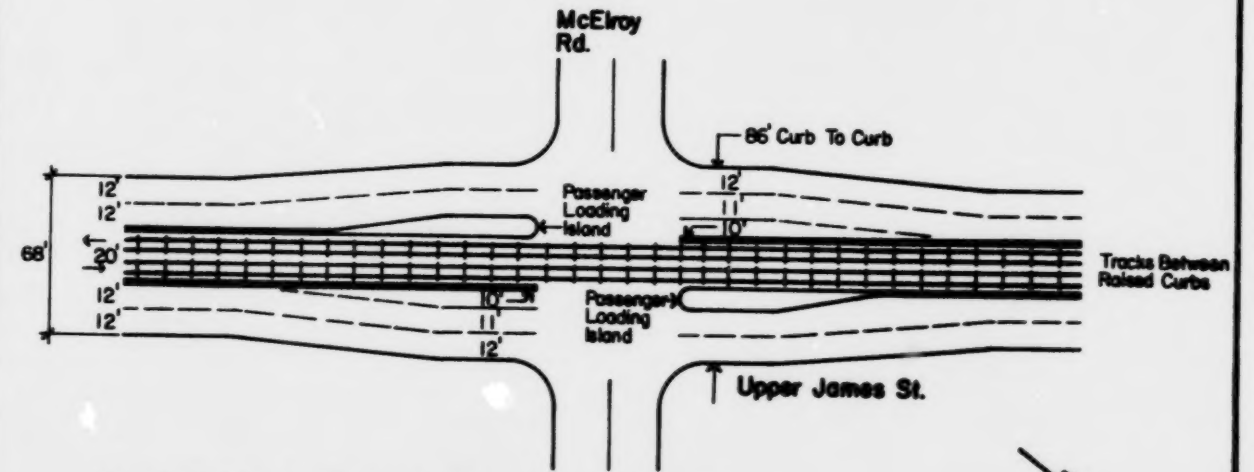
Figure 3.2



1. Existing



2. CLRV In Mixed Traffic



3. CLRV In Semi-Exclusive R.O.W.

Typical Layout Of CLRV On THE HAMN

Figure 3.3

3.1.3 - CLRV - Semi-Exclusive Right-of-Way

The assumed route alignment begins with a transit terminal situated within the Miracle Mart parking lot at the north-east quadrant of the intersection of Mohawk Road and Upper James Street (Figure 3.2). From the terminal the line curves west onto Upper James Street and proceeds north. As shown in Figure 3.3, the line consists of two single directional tracks occupying the centre portion of pavement in place of the existing centre left turn lane. It is assumed that the track area is separated from other roadway traffic by raised curbs and that no cross traffic or left turns across it would occur except at signalized intersections.

The line continues north along Upper James Street to north of Wembley Road where there is a transition from the at-grade mode to a tunnel with a centre road portal. At McElroy Road, road traffic and pedestrians could cross the alignment.

Below grade, the line curves to the east of the road allowance and enters an underground station located on the site of the Mountain Plaza Mall.

North of this station, the line curves back and continues north under Upper James Street. The initial section consists of cut and cover with a transition at Genesee Street to two tunnels descending beneath the escarpment.

The line emerges from the escarpment at a portal located in the right-of-way of the former Incline Railway, and proceeds north along the east side of James Street (additional R.O.W. required to maintain the existing four lanes), east along Charlton Avenue and north along Hughson Street (Figure 3.4).

It is assumed that Hughson Street be closed to vehicular traffic other than the CLRV and some essential local access. Traffic movements across the alignment would occur at all cross streets, although the CLRV would have the right-of-way.

In the vicinity of St. Charles Garnier Church, the line commences another transition into a tunnel, curving slightly to the west to bypass the TH&B railway terminal. The detailed design of the portals is expected to require the closure of Augusta Street and Jackson Street. Traffic movements across the alignment would occur at Charlton Avenue, St. Joseph's Drive and St. Joseph's Hospital entrance.

Rising to grade north of Hunter Street, the line proceeds north along Hughson Street, terminating at Gore Park.

Aside from the two transit terminals at Mohawk Road and Gore Park, and the underground station at Fennell Avenue, on-street transit platforms are located at several locations as indicated in Figure 3.2.

3.1.4 - CLRV - Mixed Traffic

The assumed route alignment begins with a transit terminal situated in the Miracle Mart parking lot at the north-east quadrant of the intersection of Mohawk Road and Upper James Street (Figure 3.2).

From the terminal the line curves west onto Upper James Street and proceeds north. As shown in Figure 3.3, the line consists of two single directional tracks occupying the centre portion of pavement. It is assumed that the track area is not separated from the rest of the roadway and that it may be accessible to left-turning vehicles and would not interfere with vehicular traffic at cross streets.

The line continues north along Upper James Street to Wembley Road where there is a transition from the at-grade mode to a tunnel with a centre road portal.

Below grade, the line curves to the east off the road allowance and enters an underground station located on the site of the Mountain Plaza Mall.

North of this station, the line curves back and continues north under Upper James Street. The initial section consists of cut and cover with a transition at Genesee Street to two tunnels descending beneath the escarpment.

The line emerges at-grade at a portal in the right-of-way of the former Incline Railway.

The line proceeds north along the centre of James Street to St. Joseph's Drive.

At St. Joseph's Drive, the line commences a one-way loop about the downtown (Figure 3.4). The line proceeds east along the centre of St. Joseph's Drive, turns north along the centre of John Street then west on the south branch of King Street to James Street.

At James Street, it turns and proceeds south to St. Joseph's Drive, completing the downtown loop.

On the one-way downtown streets the tracks would be located in the second lane from the right curb to avoid stopped and loading vehicles in the curb lane.

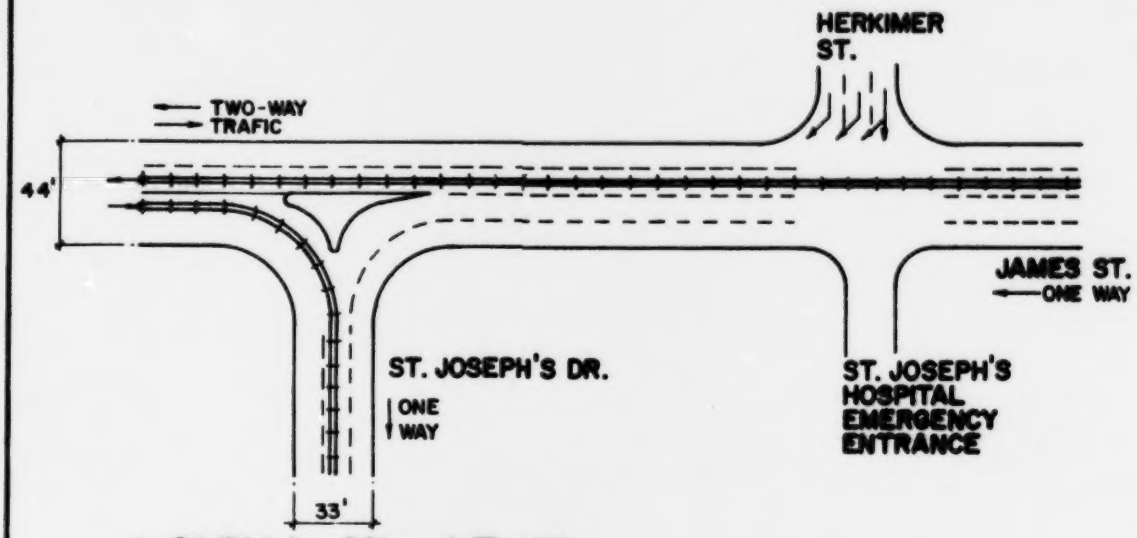
Aside from the transit terminal at Mohawk Road and the underground station at Fennell Avenue, transit stops are located at existing bus stops along the route. Pedestrians wait on the sidewalk and board the CLRV from the road when adjacent traffic comes to a halt.

Exclusive left turn lanes would not be possible on Upper James because of the tracks located adjacent to the pavement centreline.

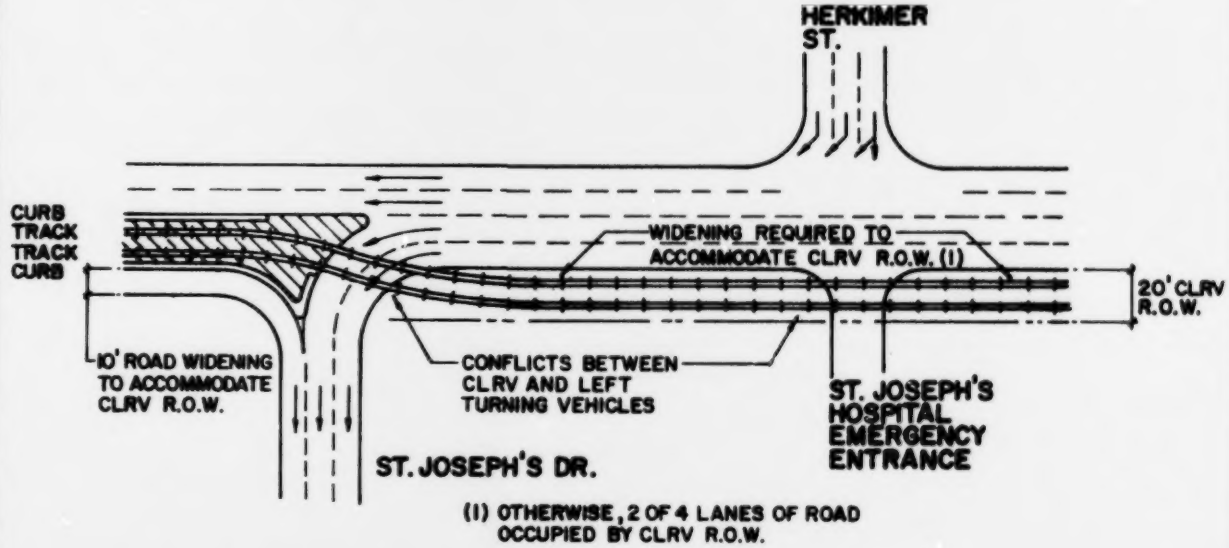
3.1.5 - On-Street Bus Transit

a) Conventional Coaches

The bus system consists of the existing Mountain routes shown in Figure 3.5. Round trip lengths remain as they are currently (Table 3.1). It is assumed that the fleet size is increased to



1. CLRV In Mixed Traffic


HERKIMER ST.
CURB
TRACK
TRACK
CURB
WIDENING REQUIRED TO ACCOMMODATE CLRV R.O.W. (1)
20' CLRV R.O.W.
10' ROAD WIDENING TO ACCOMMODATE CLRV R.O.W.
CONFLICTS BETWEEN CLRV AND LEFT TURNING VEHICLES
ST. JOSEPH'S HOSPITAL EMERGENCY ENTRANCE
ST. JOSEPH'S DR.
(1) OTHERWISE, 2 OF 4 LANES OF ROAD OCCUPIED BY CLRV R.O.W.

2. CLRV On Semi-Exclusive R.O.W.

Typical Layout Of CLRV In Downtown Area

Figure 34

accommodate the projected future 1986 demands (resulting in decreased headways) and to offset the delays resulting from expected increased road congestion until 2001.

b) Conventional Coaches, Articulated Buses and/or Trolley Buses

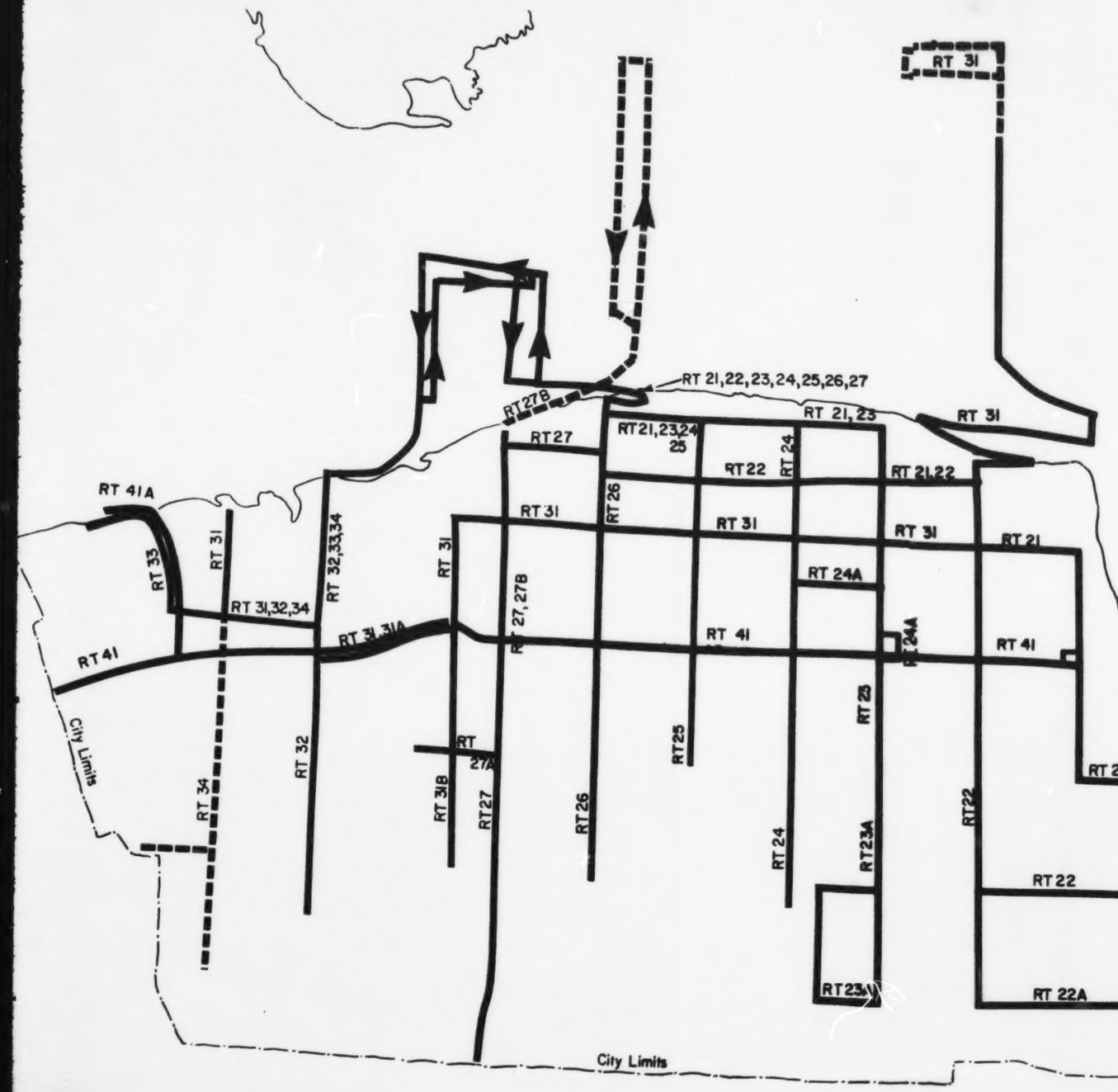
As in (a), the bus system consists of the existing Mountain routes. The fleet size is increased to accommodate the projected 1986 demands, and to offset the delays resulting from expected increased road congestion to 2001.

Two alternatives are considered. In the first alternative it is assumed that articulated buses are introduced onto the Upper Gage and Upper James routes which exhibit headways less than 10 minutes. Introduction of the articulated buses increases the headways on these routes as shown in Table 3.1. As demand increases, articulated buses may be added to other routes with high frequency service, such as Upper Wellington and Upper Wentworth.

Alternatively, it is assumed that trolley buses are introduced onto the Upper Gage and Upper James routes which exhibit headways less than 10 minutes. The Upper Gage route provides service on Concession Street. Incorporation of trolley buses would not alter the headways. In future, as demand increases, other routes such as Upper Wellington and Upper Wentworth could be electrified for trolley service.

c) Conventional Coaches In Bus Priority Lanes

As in (a), the bus system consists of the existing Mountain routes and it is assumed that the fleet size is increased to accommodate the projected 1986 demands (with conventional buses only). An existing curb lane would be restricted to transit vehicles only during the appropriate peak period. The priority lanes are assumed to permit continued bus operation at existing speeds with little impact due to road congestion. Therefore, no fleet size increases were assumed.



ROUTES

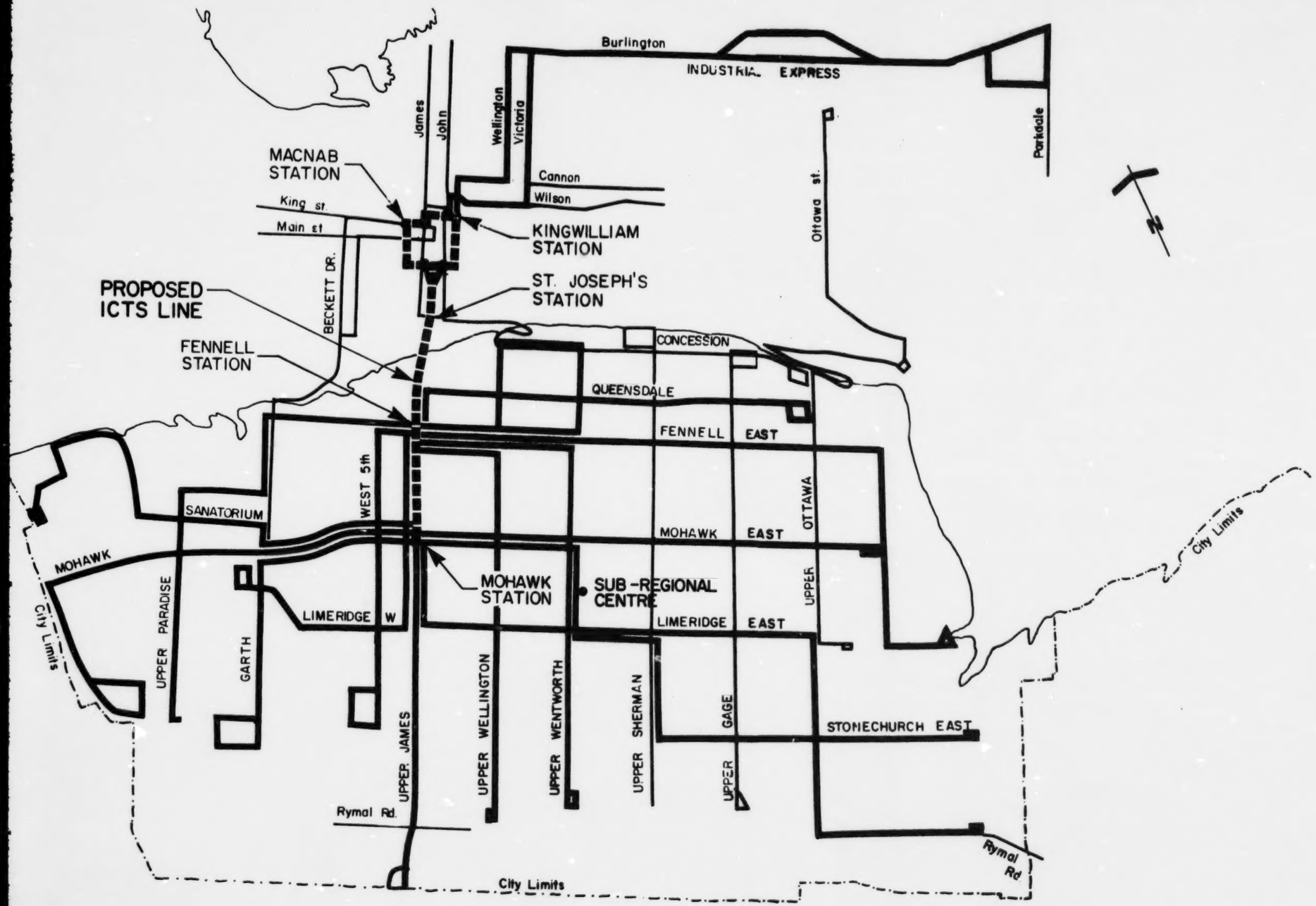
NAME	No.
FENNEL	31,31A,31B
GARTH	32
SANATORIUM	33
UPPER GAGE	23,23A
UPPER JAMES	27,27A
UPPER JAMES CLAREMONT	27B
UPPER KENILWORTH	21
UPPER OTTAWA	22,22A
UPPER PARADISE	34
UPPER SHERMAN	24,24A
UPPER WELLINGTON	26
UPPER WENTWORTH	25
MOHAWK	41,41A

Legend

- Rush Hour Only
- Daily

Existing HSR Mountain Bus Routes (1981)

Figure 3.5



Proposed Feeder Bus System on Mountain (1986)

Figure 3.6

Bus priority lanes are assumed on the Jolley Cut northbound and John Street northbound (downbound direction), during the a.m. road peak period and on James Street southbound, St. Joseph's eastbound, and the Jolley Cut soutbound (upbound direction) during the p.m. road peak period. The priority lanes would allow the buses to maintain at least the same travel time as at present, despite increasing road congestion. All other traffic will be prohibited from using the bus priority lane.

3.2 Bus Service

A feeder bus network, on the Mountain, would be required to support any of the ICTS or CLRV fixed route transit alternatives. In this investigation, it is assumed that one feeder bus system would be common to each of the alternatives.

The selected feeder bus network is presented in Figure 3.6. As shown, the feeder network services both the Mohawk and Fennell Stations, and functions as a collector/distributor of transit passengers throughout the Mountain area.

Shown in Table 3.2 are the proposed feeder bus route lengths, headways and fleet requirements. In comparison to the existing bus system expanded (Table 3.1), the feeder network provides equivalent coverage and levels of service (i.e., similar route headways) with a smaller vehicle fleet.

3.3 Transit Stations/Stops

In this report, boarding/deboarding facilities are grouped according to the following categories:

- Transit Stations - rapid transit facilities which, in general, are served by feeder buses. Walk-in passengers pay on entry to the station not on boarding the transit vehicles. In many cases, passengers transferring to/from feeder buses are dropped off in a "paid" area and do not require a paper transfer.

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Transit stations may be constructed in an elevated mode, at grade, or underground. In general, they are partially enclosed facilities offering passengers protection from rain, wind and snow.

In the case of ICTS (Elevated and Subway) and CLRV - Semi-Exclusive Right-of-Way, it is assumed that station platforms are level with the floor of the rapid transit vehicle and that vehicle boarding steps are not encountered.

- Transit Terminal - CLRV facilities generally located at the end of a line, providing means for reversing direction. In general, the terminal is served by feeder buses and may also accommodate walk-in passengers. Walk-in passengers pay on entry to the terminal. In some cases, passengers transferring to/from feeder buses are dropped off in a "paid" area and do not require a paper transfer.

  Transit terminals are constructed at-grade and are partially enclosed facilities providing limited protection from the elements. Terminal platforms are assumed to be level with the floor of the rapid transit vehicle and passengers need not climb steps to board the vehicle.

- On-Street Transit Platform - waiting area for passengers on the CLRV semi-exclusive R.O.W. consisting of a raised island constructed within the travelled portion of the roadway adjacent to the CLRV track. In general, such facilities are not enclosed and offer no protection from the elements.

  In this report, it is assumed the platforms are level with the floor of the rapid transit vehicle and that passengers need not climb steps to board the vehicle.

- Transit Stop - signed passenger waiting areas along a transit route, at frequent regular intervals.

TABLE 3.1

EXISTING MOUNTAIN BUS SERVICE EXPANDED TO 1986

	Route	Round Trip Length (km)	Headway Peak	Headway Off Peak	Daily Vehicle Kilometres	Projected Bus Requirements Peak	Projected Bus Requirements Off-Peak
21	Upper Kenilworth	21.1	12	20	1 572	5	3
22	Upper Ottawa	23.7	12	20	1 766	6	4
23	Upper Gage	21.8	8 (12)(1)	20	1 978 (1 624)	9 (2+4)(3)	3
24	Upper Sherman	18.5	15	20	1 258	4	3
25	Upper Wentworth	11.9	10	15	1 130	4	3
26	Upper Wellington	13.4	10	15	1 273	5	3
27	Upper James	18.4	8 (12)	10 (15)	2 443 (1 628)	8 (1+4)(3)	6 (1+3)(3)
27B	Upper James - Claremont	14.0	15	-	364	3	-
31	Fennell	35.6	10	15	3 382	11	6
32	Garth	14.8	15	30	799	4	2
33	Sanatorium	17.4	15	30	940	5	3
34	Upper Paradise	18.4	15	-	478	4	-
41	Mohawk	19.4	15	20	1 320	5	3
-	Limeridge	16.9	20	30	803	3	2
TOTAL		265.3			19 506 (18 337)	76 (62+8)	41 (36+3)

HOURS OF SERVICE:	5:00 a.m. - 1:30 a.m.	
A.M. Peak	6:00 a.m. - 9:00 a.m.	(3.0 h)
P.M. Peak	2:45 p.m. - 6:15 p.m.	(3.5 h)
Off Peak		(14.0 h)
TOTAL		(20.5 h)

Note: (1) Figures in brackets reflect conditions likely to occur by introducing articulated vehicles.

(2) Annual vehicle-kilometres are 6 302 400 for conventional coaches and 5 925 000 with articulated buses.

(3) Indicates number of conventional plus articulated buses.

TABLE 3.2

PROPOSED 1986 MOUNTAIN FEEDER BUS SERVICE FOR FIXED ROUTE RAPID TRANSIT LINES

Route	Round Trip Length (km)	Headway Peak	Headway Off Peak	Daily Vehicle Kilometres	Projected Bus Requirements Peak	Projected Bus Requirements Off-Peak
Sanatorium	11.8	15	20	802	3	2
Stone Church East	16.2	20	30	772	3	2
Mohawk West	13.6	15	20	925	3	2
Garth-Mohawk	10.5	20	30	500	2	1
Upper Paradise	11.4	20	30	544	2	1
Beckett Drive	10.6	20	30	506	2	1
Upper James	7.7	20	30	368	2	1
West 5th Street	10.1	20	30	480	2	1
Limeridge East	18.6	20	30	886	3	2
Limeridge West	17.8	20	30	846	3	2
Mohawk East	10.3	8½	15	1 041	4	2
Fennell East	15.6	8½	15	1 583	6	3
Queensdale	10.8	15	20	734	3	2
Upper Wentworth	11.2	20	30	532	2	1
Upper Sherman	11.9	20	30	563	2	1
Upper Gage	11.1	20	30	525	2	1
Upper Ottawa	19.7	10	15	1 873	6	4
Upper Wellington	13.6	15	20	925	3	2
Concession	13.5	10	15	1 284	5	3
Industrial Exp.	20.0	10	No Service	780	7	-
TOTAL	266.0			16 469	65	34

HOURS OF SERVICE: 5:00 a.m. - 1:30 a.m. [5 321 000](1)

A.M. Peak	6:00 a.m. - 9:00 a.m.	(3.0 h)
P.M. Peak	2:45 p.m. - 6:15 p.m.	(3.5 h)
Off Peak		(14.0 h)
TOTAL		(20.5 h)

Note: (1) Annual vehicle-kilometres.

Passengers generally wait on the sidewalk until the roadway traffic stops before boarding the transit vehicle. Fares are paid on entry to the vehicle. Passengers must climb two to three boarding steps.

In general the spacing between transit stations is greater than that between platforms which is greater than that between stops. Spacings between boarding facilities, by transit alternative are presented in the following table:

Mode of Transit	Spacings Between Boarding Facilities (Kilometres)
ICTS - Elevated	0.9 - 1.0
ICTS - Subway	0.9 - 1.0
CLRV - Semi-Exclusive Right-of-Way	0.3 - 0.7
CLRV - Mixed Traffic	0.3 - 0.4
On-Street Bus Transit[1)]	0.3

1) Based on the characteristics of Route 27, Upper James Street, north of Mohawk Road.

3.4 Maintenance Facilities

In the case of the ICTS and CLRV transit systems, the maintenance and storage yard is assumed to be located immediately south of the TH&B railway terminal in the vicinity of the intersection of Hughson Street and Haymarket Street.

For the elevated ICTS, access to the maintenance area is facilitated directly from the downtown loop. For ICTS subway, a siding would have to be provided to bring the alignment up to the grade of the TH&B tracks. This would involve a long access route to the maintenance yard. For CLRV, mixed and semi-exclusive, a siding would also have to be provided and an elevated ramp would have to be constructed up to the grade of the TH&B tracks.

In the case of the existing bus system expanded, the maintenance facility and storage yard is assumed to be provided at the H.S.R. garages on Wentworth Street (existing) and on the Mountain (planned).

4. EVALUATION CRITERIA

Performance criteria were developed on the basis of transit requirements and were selected as representative independent measures of the relative performance of each mode.

The evaluation criteria used in the comparison of alternatives and the evaluation process are grouped into the following six major headings. Further details are presented in Table 4.1.

- o System Operations - performance criteria governed by the mode of operations of each of the alternative transit systems under consideration.

- o System Design - design criteria and technological characteristics likely to affect system operations in the Hamilton Mountain Corridor.

- o Implementation - criteria which describe the impacts of the alternative transit systems during the construction period and the long term impacts following implementation.

- o Urban Impacts - criteria which describe the impacts of the alternative transit systems on the urban structure.

- o Environmental Impacts - criteria which describe the environmental impacts generated by the respective transit systems.

- o Costs - cost data including capital, operational and maintenance costs.

Table 4.1

EVALUATION CRITERIA

Evaluation Criteria	Description
1. SYSTEM OPERATIONS	
- Frequency of Service	- Comparison of the frequency of service to be provided across the escarpment, during the evening peak hour.
- Travel Time	- Comparison of travel time by mode, between the Downtown and the Mountain.
- Transfers	- Comparison of the number of transfers required during a trip by transit from the Downtown to the Mountain and the convenience associated with the transfers.
- Traffic Delays	- Comparison of the potential for delays to the transit system due to increasing traffic congestion and traffic conflicts.
2. SYSTEM DESIGN	
- Ride Comfort	- Comparison of factors contributing to the overall degree of comfort which passengers are expected to experience, i.e., system technology and stop spacing en route.
- Passenger Boarding Convenience	- Comparison of factors contributing to the ease by which passengers board vehicles, i.e., number of boarding steps, platform height, fare collection procedures and pedestrian safety.
- On-Board Security	- Comparison of the potential for vandalism on board vehicles and of emergency evacuation requirements.
- Reliability	- Comparison of the potential for system interruptions due to inclement weather or to power supply failures.
- Flexibility	- Comparison of the magnitude of capital expenditures required to increase the system capacity.

Table 4.1
(Continued)

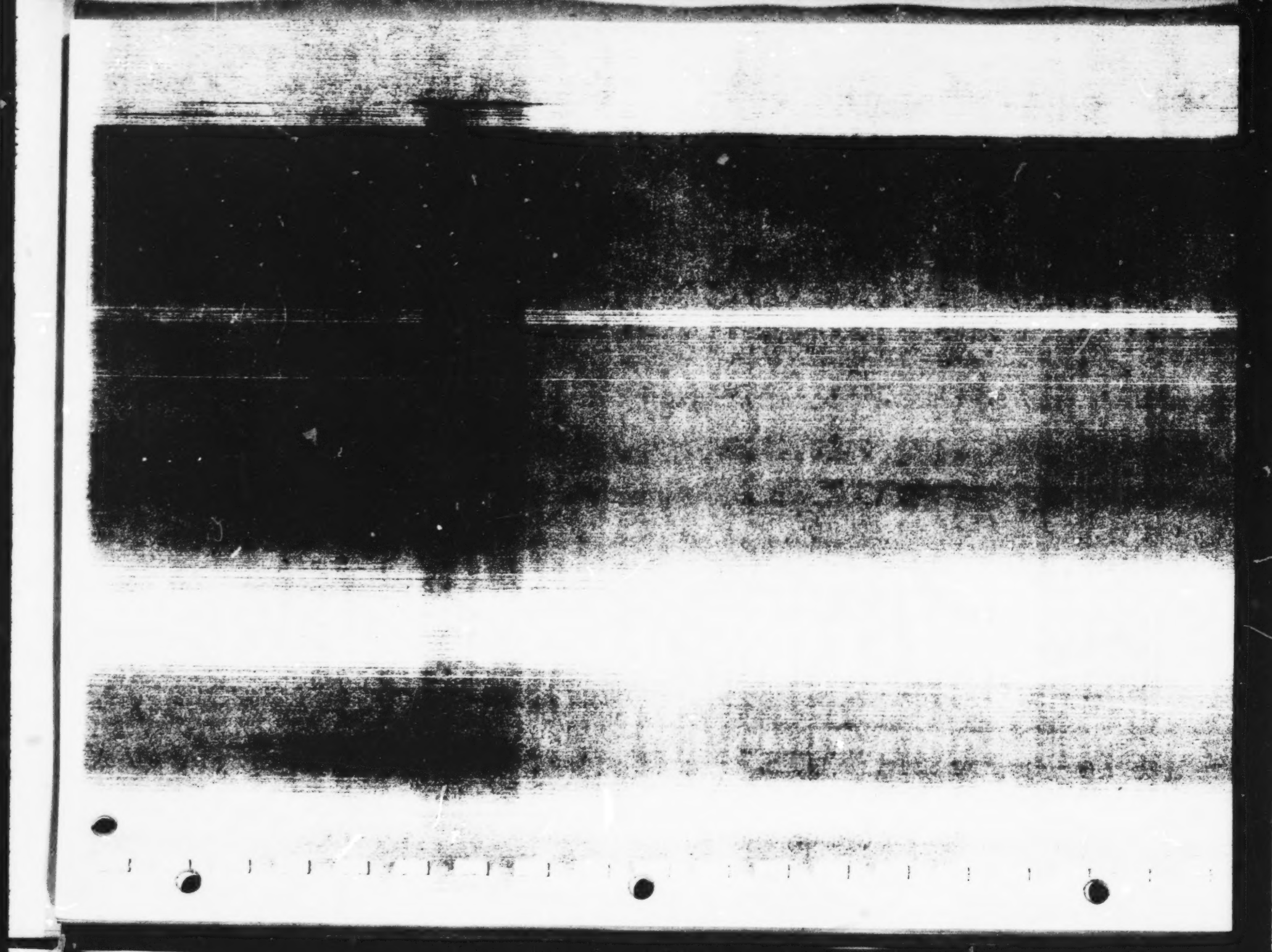
EVALUATION CRITERIA

Evaluation Criteria	Description
3. IMPLEMENTATION	
- Construction Effects	- Comparison of the type and the degree of the interruption to traffic during the contruction period.
- Land Requirements	- Comparison of land requirements beyond the public road allowance and air rights required to accommodate the alternative transit systems.
- Road Access	- Comparison of the long term impacts on turns, access and cross traffic.
- Road Capacity	- Comparison of the impacts on road capacity generated by the alternative transit systems.
4. URBAN IMPACTS	
- Visual Impacts - Mountain Area	- Comparison of the alternative systems in terms of their visual impact and effect on privacy in the Mountain area.
- Visual Impacts Lower City Area	- Comparison of visual impacts, effects on Gore Park and downtown streetscapes and effect on privacy in the downtown environment.
- Transit Image	- Comparison of the transit image created by the alternate systems.
- Support for Existing and New Development	- Comparison of the alternative modes in terms of their support for existing and new developments in the Lower City and on the Mountain.
- Support of Planning Policies	- Comparison of the level of support for City and Regional planning policies offered by the alternative transit systems.

Table 4.1
(Continued)

EVALUATION CRITERIA

Evaluation Criteria	Description
5. ENVIRONMENTAL IMPACTS	
- Noise and Vibration	- Comparison of noise and vibration impacts generated by the alternative transit systems.
- Air Quality	- Comparison of the air pollutants and levels of emission of each of the alternative systems.
- Energy	- Comparison of the type of power supply and energy consumption levels.
6. COSTS	
- Capital Costs	- Comparison of the capital costs required (1981 dollars) to implement a basic system to accommodate the 1986 projected demands and to upgrade the system to accommodate the 2001 projected demands.
- Operating Costs	- Comparison of the system operating and maintenance costs (1981 dollars) throughout the fifteen-year planning period (1986-2001).
- Total Costs	- Comparison of the combined capital, operating and maintenance costs by system (1981 dollars).



5. COMPARISON OF ALTERNATIVE MODES

5.1 System Operations

5.1.1 - Frequency of Service

The frequency of service each alternative transit system is capable of providing has been assessed for ideal operating conditions during the evening peak hour. Table 5.1 indicates the frequencies for 1986.

In order to provide the required capacity, the ICTS and CLRV transit systems each have headways of less than 3.5 minutes across the escarpment.

The ICTS operating in an elevated mode has been designed to provide a headway of 3.3 minutes or less using five (5) trains operating as married pairs.

The ICTS operating as a subway has been designed to provide a 3.2 minute headway using five (5) trains operating as married pairs.

The CLRV operating on-street in mixed traffic has been designed to provide a 2.3 minute headway using ten (10) single vehicles.

The CLRV operating on-street within a semi-exclusive R.O.W. has been designed to provide a headway of 2 minutes or less using ten (10) single vehicles.

In order to provide the required capacity at existing service levels, the on-street bus transit systems have been designed to provide headways ranging between 8 and 15 minutes depending on both the route and the fleet composition. The average combined headway of buses from all routes crossing the escarpment would be slightly greater than one minute.

Table 5.1

Comparison of Alternative Modes - 1986 Peak Hour Conditions

	ICTS Elevated	ICTS Subway	CLRV S-E ROW	CLRV Mixed Traffic	On-Street Bus Transit Expanded: Conv. Coach	Artic. Vehicle	Trolley Bus	Priority Lanes
1. Headway Crossing[1] The Escarpment								
- Train	3.3 min.	3.2	1.8[2]	2.3[2]	-	-	-	-
- Bus (per route)	10-20 min.[3]	10-20[3]	10-20[3]	10-20[3]	8-15[4]	10-15[4]	8-15[4]	8-15[4]
2. Number Crossing The Escarpment (Peak Hour, Peak Direction)								
Vehicles								
- CLRV	-	-	32[2]	26[2]	-	-	-	-
- ICTS Trains	17	19	-	-	-	-	-	-
- Standard Buses	9	9	9	9	57	43	42	-
- Articulated Buses	-	-	-	-	-	8	-	-
- Trolley Buses	-	-	-	-	-	-	15	-
Passenger Capacity								
- Total	3 135	3 435	3 625	3 055	3 705	3 755	3 705	3 705
- Seated	1 497	1 617	2 109	1 803	3 021	2 783	2 856	3 021
3. Traveltime on Transit[7] Downtown To: (min.)								
Fennell/Upper James	7.1	6.5	7.1	9.8	17.0	19.0	17.0	17.0[8]
Fennell/Upper Sherman	19.0	18.4	19.0	21.75	23.0	23.0	23.0	23.0
Fennell/Upper Ottawa	23.8	23.25	23.8	26.5	27.5	27.5	27.5	27.5
Mohawk/Upper James	9.25	8.7	9.8	14.0	19.8	21.8	19.8	17.8
Mohawk/Garth	17.25	16.7	18.75	22.0	18.5	18.5	18.5	18.5
Mohawk/Upper Wentworth	17.25	16.7	18.75	22.0	22.5	22.5	22.5	22.5
Mohawk/Upper Ottawa	26.1	25.5	27.5	30.9	30.5	30.5	30.5	30.5
Upper James/Rymal Road	28.75	28.2	30.25	33.5	31.5	33.5	31.5	31.5
Mohawk/Magnolia	27.5	26.9	29.0	32.25	30.0	30.0	30.0	30.0
Stonechurch/Upper Ottawa	32.5	31.9	34.0	37.25	34.5	34.5	34.5	34.5
4. % of Transit Riders Residing Within "X" Min. Travel Time of the CBD.								
Within 15 minutes	5%	5%	5%	1%	1%	1%	1%	1%
Within 20 minutes	35%	35%	25%	15%	15%	15%	15%	15%
Within 25 minutes	65%	65%	55%	35%	40%	35%	40%	40%
Within 30 minutes	85%	85%	70%	55%	65%	60%	65%	65%

(1) Table refers to section of the escarpment within the Mountain corridor.
(2) Practical headway will be limited by tunnel signal system and may not be less than 2-2.5 minutes (24-30 vehicles per hour).
(3) Based on Mountain feeder bus routes: - Concession Street Route - 10 minute headway
- Beckett Drive Route - 20 minute headway
(4) Based on projected headways for the on-street bus system expanded.
(5) Based on loads of 75 per ICTS vehicle, 95 per CLRV, 65 per bus, 65 per trolley bus, and 120 per articulated bus. These loads are based on existing HSR comfort standards.
(6) Based on 30 seats per ICTS vehicle, 51 seats per CLRV vehicle, 53 seats per conventional coach, 42 seats per trolley bus and 63 seats per articulated vehicle.
(7) The alternative systems have different downtown stations as indicated in Figure 3.
(8) Under 1986 conditions, travel times in priority lanes will not vary significantly from travel times in mixed traffic.

5.1.2 - Travel Time

Estimates of travel times from the downtown to various points on the Mountain shown in Table 5.1 indicate that for these routes the ICTS elevated or subway provide comparable travel times.

The CLRV operating on a semi-exclusive right-of-way provides travel times comparable to the ICTS modes, while the CLRV operating in mixed traffic is somewhat slower.

The longest travel time to most of the selected points occurs with the on-street bus system. The bus travel times will continue to increase with increasing road congestion in the future. Because the other modes are less susceptable to the effects of traffic delays, the travel time difference between buses and the other modes will also increase.

Both ICTS modes and the CLRV operating on a semi-exclusive right-of-way are capable of accommodating a greater proportion (36% for both ICTS, 25% for CLRV semi-exclusive) of transit riders residing within 20 minutes of the downtown than the other systems (15%). This is due to the short travel time on these systems and the concentration of feeder bus routes in the vicinity of the Mountain transfer points.

ICTS and CLRV semi-exclusive have a similar advantage for transit riders residing within 25 minutes of the downtown.

5.1.3 - Transfers

An expanded bus system is expected to have the best transfer characteristics of all transit modes examined. Currently, most passengers who board the existing bus system in the downtown are not required to transfer to reach destinations on the Mountain. Most passengers travelling on the proposed CLRV or ICTS systems will have at least one transfer to the feeder bus network (or automobile), except the 3 - 4% of riders who live within walking distance of the stations.

The existing bus system requires only 5% of riders to transfer to other HSR routes on the Mountain. Approximately the same pattern of transfers is anticipated for the expanded bus systems, since the same bus routes are involved.

Although patrons of ICTS and CLRV systems will be required to transfer, it is expected that this activity will be convenient. Most transfers to the feeder bus system will be "paper-free" and take place under weather protected conditions. In addition, there may be an opportunity for "kiss 'n ride" and commuter parking.

In the downtown area, the transfer patterns will remain basically unchanged (i.e., 66 percent of all transit riders walk to their destination from the buses) except that passengers will have a choice of two stations for the ICTS elevated mode.

5.1.4 - Traffic Delays

Being in a completely exclusive right-of-way, the ICTS systems (elevated or underground) are the only modes which are not subject to potential delays from increasing traffic congestion or traffic conflicts. The other transit modes are subject to such delays.

Bus systems operating in mixed traffic will be subject to delays due to traffic congestion, turning vehicles, cross traffic and traffic conflicts. These delays are expected to increase as travel demand in the Mountain corridor, particularly across the escarpment, reaches practical capacity in the late 1980s or early 1990s and road congestion increases.

The CLRV operating in mixed traffic will be subject to delay due to traffic congestion, turning vehicles, cross traffic and traffic conflicts, particularly in the downtown. The CLRV operating on a semi-exclusive right-of-way will be subject to delays caused by cross traffic and traffic conflicts at signalized intersections.

5.2 System Design

5.2.1 - Ride Comfort

Passengers on the ICTS systems are expected to experience greater degrees of ride comfort than those riding the CLRV or bus systems. Such comfort will be derived from smoother acceleration/deceleration profiles which can be achieved from the sophisticated controls combined with the independent guideways and wide stop spacing (refer to Section 3.3).

Ride comfort for all other systems will be limited by the experience and capabilities of the driver and the frequency of designated transit stops en route. Bus systems and the CLRV in mixed traffic will be subject to random stops due to congestion, cross traffic and turning vehicles. Although both CLRV systems will provide a smooth ride by virtue of the rails, the CLRV on a semi-exclusive right-of-way will be subject only to interruptions by cross traffic, which will have some adverse effect upon ride comfort. Therefore, passenger comfort on CLRV on semi-exclusive R.O.W. will be greater than CLRV in mixed traffic, which will in turn be greater than on buses.

5.2.2 - Passenger Boarding Convenience

All the transit systems studied require that most passengers board a bus at least once during a trip between the Downtown and the Mountain, with the exception of those few passengers who live within walking distance of an ICTS or CLRV station.

The bus systems provide for on-street passenger boarding from the curb lane. Passengers not living within walking distance of stations will be exposed to inclement weather at bus stops when travelling in the Mountain-to-downtown direction. However, for downtown-to-Mountain trips, the ICTS provides a higher level of comfort as waiting times are spent at stations.

The ICTS system should be convenient for passenger boarding because of the number of vehicle doors, platforms level with vehicle floor height, fare collection at station entrances, and weather protected platforms. Boarding times of approximately 1.0 second per passenger per door should be achievable for the ICTS systems.

The CLRV on a semi-exclusive right-of-way would also have good loading characteristics at major stations with fare collection at station entrances. Boarding times similar to the ICTS could be expected as both front and rear doors could be used for boarding.

The CLRV in mixed traffic and the bus systems all require approximately 1.7 seconds per passenger per door (and only the front door can be used) for boarding when using an exact fare system. Deboarding in an articulated bus can be somewhat faster since three sets of doors are provided.

The CLRV systems pose a potential safety problem to pedestrians crossing traffic lanes to board transit vehicles or to reach on-street loading platforms.

5.2.3 - On-Board Security

Complete operational safety on both ICTS modes is maintained by a sophisticated train control system which eliminates the possibility of ICTS vehicles contacting or colliding. Station attendants have been assumed to be provided at all ICTS stations, however, neither mode requires on-board operators or attendants. Two-way radio communication and emergency warning devices are provided in all vehicles.

The ICTS vehicles are provided with sufficient emergency braking capability to remain stationary on inclined guideway segments should they become disabled. Evacuation from an elevated guideway is possible via walkways and emergency stairs.

Both of the CLRV modes will be driver-operated. However, travel through the tunnel segment will likely require a signal control system to ensure safe operation.

Evacuation from the tunnel segment for all ICTS and CLRV modes is possible via walkways and emergency exits. The tunnels are equipped with emergency lighting. For ICTS modes, a back-up generator can be provided to maintain sufficient emergency power to permit removal of one train at a time at reduced speed while maintaining minimum power to other trains.

The presence of an operator in both of the CLRV modes and on all buses will discourage on-board vandalism.

5.2.4 - Reliability

The reliability of each alternative transit system is measured in terms of frequency and severity of service disruption and the sensitivity to adverse weather conditions.

All electrically powered systems are subject to disruption due to hydro electric power failures. However, it is understood that such failures are very infrequent.

Should the automatic control system fail, the ICTS modes cannot provide immediate driver override as operator/attendents are not provided. The ICTS technology has undergone extensive design and testing to ensure a high degree of reliability. Adverse weather conditions will not affect ICTS vehicle traction or overall performance.

Both CLRV modes will be subject to minor disruptions due to loss of contact between the trolley pole and the overhead power supply on turns etc. Adverse weather conditions may somewhat affect CLRV vehicle traction provided through wheel-rail contact, particularly in the tunnel segment where ice buildup on the track may occur.

The reliability of bus systems utilizing conventional or articulated buses is a function of the reliability of the individual vehicles. Articulated buses will be introduced in Ontario in the near future to undergo demonstrations in revenue service.

Trolley bus service reliability is a function of both the individual buses and the power supply system. System disruption due to damage to the overhead power supply, as well as minor disruptions due to loss of contact with the overhead power supply are possible.

Severe weather conditions can affect the reliability of bus systems through loss of traction with the road surface.

The ICTS and CLRV systems both depend on a few vehicles (5 - 2-car trains for ICTS; 10 single vehicles for CLRV) each carrying a relatively large number of passengers and making frequent trips across the escarpment during the peak hour. In comparison, many more buses each carrying a smaller passenger load will only cross the escarpment 1 - 2 times each during the peak hour. Therefore, the failure of single ICTS vehicle (which may remove a 2-vehicle train from service) will result in a significant reduction in the level of service provided. A CLRV vehicle failure will have a less severe impact than an ICTS vehicle failure, but the impact will be more severe than a single bus failure.

5.2.5 - Flexibility

The degree of flexibility of each alternative transit system is determined by whether the system has a permanent guideway or power supply.

The feeder bus system serving the ICTS or the CLRV systems and the on-street bus system expanded offer equal flexibility for rerouting or expansion. The capacity of the bus systems can be expanded readily in the short-term by incrementally increasing the fleet size by adding a small number of buses at relatively low costs per vehicle. Trolley

buses operate on a fixed route due to the overhead power supply, however, route extensions and rerouting are possible with capital investment for new overhead wires, and for buses which cost approximately 30 - 35% more than conventional buses. In the long-term, increasing on-street traffic congestion particularly in the Lower City and on Mountain access routes, and the concentration of buses in the Gore Park terminal area may restrict the ability of bus based systems to provide reliable convenient service as passenger demand increases.

Bus priority lanes are a means of improving the reliability and travel time of the on-street bus system in heavily travelled corridors.

All other systems have permanent guideways and offer little opportunity for short-term physical expansion to provide new routes due to the scale of capital investment, the requirements for long-term planning, and the time period required for the actual construction of additional guideway or trackage and stations.

The capacity of the ICTS operating in an elevated mode or subway can be increased to meet demand on existing routes by adding extra trains. The automatic control system can provide for headways as low as 60 seconds. This will create a heavy concentration of vehicles on the final system.

Capital cost investment for line extension of the ICTS operating as a subway would be higher than for ICTS operating in an elevated mode. However, possible route extensions and station locations may be more easily selected because of lesser perceived impacts.

The expansion of the CLRV operating on-street in mixed traffic will require additional at-grade trackage at significant capital investment. Capacity can be increased to meet demand on the existing route by adding additional vehicles and reducing headways, however, the CLRV must still interact with other vehicular traffic and schedule adherence cannot be guaranteed. Moreover, control systems for the tunnel segment may limit the practical headways on the route.

Physical extension of the CLRV operating on a semi-exclusive right-of-way is restricted in the long-term even more than the CLRV operating in mixed traffic, since an exclusive right-of-way operation is limited to streets with sufficient road allowance width to permit introduction of reserved median area without road widenings which could have a significant impact on adjacent properties. Capacity can be increased by adding extra vehicles. The physical separation from other traffic will facilitate schedule adherence, however, the limited interaction with other vehicular traffic may disrupt service somewhat.

5.3 Implementation

5.3.1 - Construction Effects

The expanded bus systems have no significant impacts due to construction, assuming no new traffic lanes are required.

The CLRV and ICTS systems may require the closure or restriction of streets during construction. The elevated ICTS system will result in short term disruption to traffic during pouring of footings and columns, but the use of precast components for the guideway should shorten the length of the disruption. The ICTS underground system may result in long term traffic disruption and partial road closings to accommodate cut and cover construction.

The CLRV transit modes require some short term road closings to accommodate construction of tracks and switches, but the disruption will not be as severe as the ICTS underground system.

5.3.2 - Land Requirements

The purpose of this report was to compare alternative modes. Representative alignments were selected for general comparison without detailed study of routing to minimize impacts. Therefore, a comparison of land requirements must be undertaken with care and must be general in nature.

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The ICTS and CLRV modes have the same station land requirements on the Mountain, with the exception that the CLRV turnaround loops at Mohawk require more land. Station requirements downtown are similar, except that the second ICTS station (King William) is off-street (but would likely be integrated with an inter-regional bus terminal) and the CLRV semi-exclusive requires a turnaround loop with significant potential impact on Gore Park.

With respect to property requirements along the route, ICTS subway and CLRV in mixed traffic are located entirely within existing roads. ICTS elevated also generally fits within existing roads with the exception of air rights in several locations downtown (for the loop) and possible minor road widenings in the vicinity of St. Joseph's Hospital (subject to detailed design).

In general, the CLRV semi-exclusive R.O.W. has the greatest property impact since it requires a separate R.O.W. at least twenty feet wide to avoid removing existing traffic lanes. On the Mountain, the existing Upper James Street road allowance will accommodate the CLRV on semi-exclusive R.O.W., but pavement widening is required. Downtown, additional property is required along James Street (adjacent to St. Joseph's Hospital) and possibly Charlton Avenue. No property is required on Hughson Street, but the entire street must be closed to non-transit traffic.

5.3.3 - Road Access

The ICTS underground systems and the expanded bus systems have no impacts on road access or on-street parking.

The CLRV (semi-exclusive rights-of-way) will have an effect upon more properties than any other mode including major restrictions on turns, access and cross traffic.

On Upper James Street, the median location for CLRV will block left turn access to all streets and properties between Fennell and Mohawk

stations, except at McElroy Road where left turn lanes and special traffic signal phasing would be required. Loss of left turn access into large commercial properties such as Mountain Plaza Mall and Miracle Mart would be unacceptable and could only be avoided by left turn lanes and traffic signal treatments similar to that at McElroy, which would cause undesirable delays to both road traffic and transit.

In the lower city, CLRV (semi-exclusive) would cross several streets and driveways to St. Joseph's Hospital. It would require closure of Hughson Street to all traffic except essential local access to properties, elimination of all on-street parking (27 spaces) on Hughson Street, and elimination of vehicle loading on the narrow section of Hughson Street north of Main Street.

The CLRV on a semi-exclusive R.O.W. will require closure of Augusta and Jackson Streets at Hughson Street to accommodate the transition from at-grade operation to a tunnel.

With CLRV in mixed traffic, there would be no interference with access, although left turning traffic on Upper James Street (particularly at the shopping centre entrances) could result in significant delay for transit vehicles.

ICTS elevated would eliminate a few parking spaces on Hughson Street and on King William Street, and would block left turns to several dwelling units and commercial properties on Upper James Street between Fennell and Mohawk stations.

The other modes would not have an impact on road access or parking.

5.3.4 - Road Capacity

Buses in reserved lanes will have the greatest impact on traffic by removing one lane of capacity (approximately 770 vehicles or 1 000 persons at 1.3 persons per vehicle) from the Jolley Cut and from James Street or John Street.

It should be noted that the transportation planning in the Region, particularly the Transportation Capital Facilities Plan, is based on the assumption that a rapid transit line would eliminate virtually all buses from the Jolley Cut. Therefore, all lanes would be available for automobile traffic. However, installation of a priority lane for buses would reduce the capacity across the escarpment (screenline 15) by approximately 770 vehicles per hour, or 12% of the total capacity shown in the Transportation Capital Facilities Plan.

Even without a priority lane, the increasing number of buses operating across the escarpment without a rapid transit system, would effectively utilize one traffic lane and significantly limit the number of non-transit vehicles using that lane.

The ICTS elevated, ICTS subway, and CLRV semi-exclusive right-of-way systems have little or no impact on major road capacity. This assumes that in the case of CLRV, or possibly elevated ICTS, a widening can be obtained on the east side of James Street from James Mountain Road to Charlton Avenue to maintain three lanes to the south and four lanes to the north of St. Joseph's Drive. The CLRV crossing of traffic at the James Street/St. Joseph's Drive and the Charlton Avenue/Hughson Street intersections may require road traffic to yield, or installation of traffic signals which could affect capacity at this critical point.

In the case of both CLRV (mixed traffic) and the expanded bus system, vehicles stopping at transit stops would block one lane in the case of buses, and two lanes in the case of CLRV which operates in the second lane from the curb.

5.4 Urban Impacts

5.4.1 - Visual Impacts - Mountain Area

The expanded bus systems and the ICTS underground line are significant visual impacts in the Mountain area.

The ICTS elevated system has the largest visual impact in the Mountain area because of invasion of privacy and obstruction of axial views along Upper James Street. Views from the vehicles of this system result in some invasion of privacy at the second storey of adjacent residences. It also causes some interference with views from buildings, particularly just north of the Miracle Mart. None of the other systems have this effect.

The ICTS elevated system and CLRV semi-exclusive right-of-way both affect views down Upper James and across it. The ICTS elevated has a general interference with the street space while CLRV on semi-exclusive right-of-way essentially divides the street space, especially if it is fenced or landscaped. The centre road portal for both CLRV modes also divides the street.

The wires of the CLRV and trolley coaches add to visual clutter in the street space, but this is considered to be a minor impact.

5.4.2 - Visual Impacts - Lower City Area

The expanded bus systems and the ICTS underground mode would have no significant visual impacts in the Lower City area.

The CLRV on a semi-exclusive right-of-way will have the maximum visual impact upon the downtown area. If it is necessary to fence the rights-of-way, severe impacts upon the views down the narrow streets carrying the route would cause a significant visual disruption. This situation could be especially severe in views of the tunnel portals along Hughson Street near the TH&B station.

The CLRV on a separate right-of-way with its station in Gore Park would require extensive revisions to the park resulting in visual disruption in the area. Its turn-around loop presents a design problem and could reduce the park area considerably.

The overhead wires of CLRV or trolley coaches will detract from the existing spatial environment, particularly along James Street and at Gore Park.

With both types of CLRV systems, the at-grade track-bed sloping down from the portal in the escarpment will be exposed in major views of the escarpment, whereas the major views of ICTS elevated will be primarily the concrete structure, not the track-bed. For the CLRV modes, the portal transition zone is much longer than for elevated ICTS.

The elevated ICTS guideway would have a strong and large-scale impact upon existing street spaces, especially on King, James and King William Streets.

The elevated ICTS system increases the invasion of residential privacy to a few apartments on Hughson Street. It also affects some views from the Hughson Street apartments and detracts from the principal view of the St. Charles Garnier Church. However, it does provide passengers with new and interesting views of city landmarks such as Whitehern.

5.4.3 - Transit Image

The ICTS systems would both give Hamilton's downtown a rapid transit image. The ICTS elevated system may provide a more forward-looking and exciting image than underground ICTS because of the visibility of its stations and the modern vehicles on the elevated guideways.

The CLRV systems would improve Hamilton's transit image but would not provide as significant a change as the ICTS. There would be little or no improvement in the City's transit image with any of the expanded bus systems.

5.4.4 - Support for Existing and New Development

The elevated ICTS provides the best support for existing and future development. On the Mountain, both ICTS systems will promote the development of more dense commercial/residential nodes in Mohawk and Fennell station areas with some increases of residential densities along major bus arterials approaching these stations.

In the Lower City area, the elevated ICTS provides better support for development than the underground system because it has two stations in areas with development potential compared to the single station at Gore Park.

MacNab Station is central to the existing CBD office/institutional node west of James Street. After development of the Jackson Square block is complete, new development will depend on redevelopment of moderate-sized office buildings.

King William Station as the proposed interface with inter-regional transit provides some support for the high density node developing in the King/Catharine area. Further development would require the use of parking lots or the redevelopment of three to five storey buildings north of King. Development opportunities south of King near this mode are somewhat distant from the station.

Finally, the elevated ICTS best supports plans for a plus 15 pedestrian mall west of James in the King Street area with the MacNab Station as a cross-road.

An underground ICTS would centralize support for the downtown CBD in a Gore Park Station. It promotes the regeneration of the Gore Park commercial buildings as the downtown centre but does not promote growth in an easterly direction.

The CLRV on a semi-exclusive right-of-way could support a north/south series of moderately dense nodes in the Hughson Street corridor. The Gore Park terminal would be the major downtown focal point with most of the existing and planned central business development relying on the east/west bus system. Development opportunities around the TH&B station would be promoted and the TH&B station itself would be a logical location for a major transit interchange.

On the Mountain, the semi-exclusive CLRV poses some restrictions on commercial development and may result in lower densities overall due to expected longer travel times, poorer station/development connections and larger station areas, all of which may affect the attractiveness of station areas as locations for development.

The CLRV in mixed traffic, which would generally serve the same areas as the present bus system, could result in the sporadic redevelopment of sections of these areas with medium density commercial or residential uses but without any specific nodal concentration.

The CLRV in mixed traffic with longer travel times and more stops may only result in moderate increases in residential and commercial densities and may be more linear than nodal in form.

An expanded bus system is not expected to exert a significant influence to increase existing densities nor to alter the present form of development.

5.4.4 - Support of Planning Policies

The ICTS elevated system provides the best support for the planning policies of the City and Region because of its development potential and ability to attract new ridership. At the other extreme, the expansion of the bus system does not support most transit-related policies.

The 1980 Regional Official Plan contains several policies which affect the development of transit systems:

- Downtown Hamilton will be the focal point of transit service.
- The need for automobile use in the CBD will be reduced.
- Higher density uses should locate in new transit corridors.
- the integration of terminal facilities and transit is encouraged.
- long term commuter parking in the Hamilton CBD is discouraged.

These policies were confirmed in the City of Hamilton Draft Official Plan which requires that the need for new road facilities in congested corridors should be minimized and specifically mentions:

> "Council may consider the potential of a new and innovative intermediate capacity transit line connecting downtown Hamilton to an appropriate location on the Mountain" (Section 3.2.11)

At present, some of the City's neighbourhood plans provide support for rapid transit oriented development while others, particularly those for established neighbourhoods above the escarpment, would have to be reviewed for the new route proposals.

The ICTS elevated system provides the best support for the development of the CBD because its station locations are the most convenient to existing and planned development. This system also provides the greatest opportunity to increase transit use and avoid major increases in parking. The ICTS elevated system will require changes in neighbourhood planning policies around Fennell and Mohawk stations to permit transit-oriented development.

The ICTS underground system is similar to the elevated system except that it provides a lower level of support for CBD development due to its single downtown station at Gore Park and lower visibility in the area.

The CLRV mixed traffic system provides little support for the CBD development and transportation policies of the City and Region. However, it is more compatible with present development plans in the St. Joseph's station area and on the Mountain. The CLRV on a semi-exclusive right-of-way presents some severe difficulties for downtown development and pedestrian and vehicular circulation, especially if fences are required. The semi-exclusive right-of-way in the St. Joseph's station and Mountain areas could be even more of a barrier to neighbourhood communication than the ICTS elevated guideway.

It is clear that, in the long term, an expanded bus system does not adequately satisfy public policy with regard to encouraging transit in the CBD and providing a rapid transit link between the Mountain and Downtown, as noted in Section 2 of this report. The use of exclusive bus lanes, articulated buses or trolley coaches would carry more people across the escarpment to the lower city but it would not result in any appreciable strengthening of the Central Business District or a reduction in travel times as could the ICTS or CLRV semi-exclusive modes. An expanded bus system may require the construction of additional road capacity in the congested Mountain Access corridor and exclusive bus lanes would also hasten the requirement for additional facilities.

None of the alternative transit systems considered in this report directly support the creation of a Sub-Regional Centre development around the Limeridge Mall or its function as a transit interchange. However, any of the ICTS or CLRV systems could be expanded to this location in the future.

5.5 Environmental Impacts

5.5.1 - Noise and Vibration

The most commonly used term for describing community noise is L_{eq} which is defined as the steady sound level which would contain an energy content equivalent to that of the time-varying sound levels

during a measurement period. This energy average is employed by the Ontario Ministry of the Environment, using one hour L_{eq} as their basic guideline for determining noise standards.

The construction of CLRV and ICTS systems would require the use of heavy construction equipment. The extent of noise and vibration impacts would depend upon ambient conditions, actual levels produced by the noise and vibration sources and the proximity of the affected receivers. No construction-related impacts would be incurred with increased use of trolley buses, articulated buses and standard buses operating on existing road networks.

In terms of operations, noise and vibration impacts will vary depending on the type of transportation mode. Based on information supplied by personal communication with the Ministry of Transportation and Communications, an assessment of noise levels produced by ICTS, Heavy Rail Transit (HRT - i.e., Toronto Subway), standard buses, articulated buses and articulated CLRV travelling on a straight track at 60 km/h, indicated that the noise produced was lowest with trolley buses and highest with HRT (subway).

It should be noted that while standard buses, articulated buses, and CLRV produce approximately the same level of noise at 60 km/h, the action of starting and stopping at stations would create a higher noise level for buses than for any alternative. The solution of increasing the number of buses in the study area would only add to the noise impact to be absorbed by the community.

In addition, the Ministry of Transportation and Communications has found that ICTS produces about 10 dBA less noise than CLRV or buses, which represents a two-fold reduction in noise level. HRT produces the highest noise level, but is mainly located underground which significantly dampens the resulting noise and vibration.

ICTS, CLRV or articulated buses would reduce bus traffic and thus reduce the associated noise level.

Impacts due to vibration are difficult to ascertain at this stage of the planning process, without the availability of detailed design drawings and soils analysis reports. It is suggested that potential vibration impacts could be identified and corrected during detailed design of any of the systems.

5.5.2 - Air Quality

The impact on air quality varies significantly from one mode of transportation to another.

Standard and articulated buses powered by gasoline or diesel engines produce sulphur dioxide, particulate matter, nitrous oxide, carbon monoxide and hydrocarbons.

The Ontario Ministry of the Environment, Air Resources Branch has found that the rate of emissions for articulated buses is 45% greater than the rate produced by standard buses.(1) Exact results on the above air quality parameters are shown in the following table.

	Standard Bus		Articulated Bus	
	Kilograms Per Million:		Kilograms Per Million:	
Exhaust Emissions:	Vehicle-km	Passenger-km	Vehicle-km	Passenger-km
Sulphur Dioxide	1 745	23.3	2 530	19.4
Particulate-Matter	810	10.8	1 175	9.1
Nitrous Oxide	13 360	178.8	1 940	149.0
Carbon Monoxide	13 235	17.6	1 920	147.6
Hydrocarbons	2 490	33.2	3 610	27.8

(1) Personal communications with Ministry of Transportation and Communications.

Since ICTS, CLRV and trolley buses are all powered by electricity, the vehicles do not produce air pollutants. Use of these vehicles would create minor additional air pollution from power plants. The ICTS and CLRV systems would eliminate approximately 40 buses per hour downtown, resulting in a corresponding decrease in diesel emissions.

Besides operational impacts, the construction of tracks, guideways and rights-of-way, will impair local air quality, depending on the type of construction equipment used, the type of construction techniques employed and the ambient air quality. Construction-related emissions associated with ICTS and CLRV would include dust, fumes, carbon monoxide, nitrogen oxides and sulphur dioxide. No construction-related impacts would be incurred with the implementation of trolley buses, standard buses or articulated buses travelling on existing road networks.

5.5.3 - Energy

The fuel efficiency of the various modes of public transit is affected by the distance between stations; the size of the load; and the losses in energy resulting from the production of power and the creation of vehicular motion. Generally, the fuel efficiency of the vehicles increases as the distance between stations increases. Fuel efficiency also increases as the numbers of people using the system, at any one time, increases.

All modes of public transit experience some loss in energy between the power and drive mechanism. In buses and other self-contained powered units, for example, these losses are created during the transformation of the fuel into power, and during the transfer of the power from the engine to the wheels. In electrically-powered vehicles, the losses are experienced at the power plant and, to a lesser extent, along the hydro lines and in the transformation of the energy into motion.

A generalized comparison of the energy requirements for various modes of public transit is given in the following table.(1) Though the figures cited may vary, depending on the distance between stations and the size of the load, the ICTS system is shown to have the lowest energy consumption rate per vehicle kilometre and per passenger kilometre of those systems examined.

ICTS	4 450 BTU per veh km	105 BTU per pass km(2)
CLRV	3 500 BTU per veh km	111 BTU per pass km
Standard Bus	13-18 000 BTU per veh km	173-240 BTU per pass km
Articulated Bus	19-26 000 BTU per veh km	146-200 BTU per pass km
Trolley Bus	7 850 BTU per veh km	100-120 BTU per pass km

(2) at design load.

5.6 Costs

Presented in Table 5.2 are the estimated capital, operating and maintenance costs of the alternative transit systems. The costs are expressed in 1981 dollars. Cost data for the ICTS and CLRV systems was provided by the Urban Transportation Development Corporation. Bus cost data was obtained from HSR and published CUTA statistics.

5.6.1 - Capital Costs

The estimated capital costs represent the cost to implement the basic 1986 system (bus system or rail system supported by feeder buses), plus the cost of the required fleet expansion to accommodate the projected future increase in transit ridership between 1986 and 2001. An inflation rate of 12 percent per year was assumed to estimate future capital costs. These were discounted using an interest rate of 15 percent per annum.

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(1) Personal communication with Ministry of Transportation and Communications.

Included in the basic 1986 systems costs are the costs of fixed facilities, command control equipment, power systems and the cost to purchase new vehicles where required such as, 10 ICTS cars in the case of the ICTS systems, 10 CLRV's in the case of the CLRV systems and 17 trolleys in the case of the trolley bus system. In the case of the bus and feeder bus systems, it was assumed that the cost to purchase a new fleet of conventional buses or 8 new articulated vehicles was not warranted, that articulated vehicles would replace some conventional vehicles over time, and that, to accommodate the feeder bus network, buses already available in the existing HSR system would simply be reassigned. However, replacement costs for the 1986 basic bus fleet, that is the cost to replace buses as they wear out over time, were included.

These were calculated on the basis of total system vehicle-kilometres operated per year using an estimated lifetime per bus also expressed in vehicle-kilometres.

No consideration was given to the cost of existing road facilities which are assumed to provide the right-of-way on which the buses operate.

Included in the 1986 - 2001 fleet expansion costs are 10 additional ICTS cars in the case of the two ICTS systems, 10 additional CLRV's in the case of the CLRV system operating in a semi-exclusive right-of-way, 12 additional CLRV's in the case of the CLRV system operating in mixed traffic, 46 additional conventional buses in the case of all feeder bus systems and 63 to 72 additional buses in the cases of the other bus systems.

5.6.2 - Operating and Maintenance Costs

The estimated operating and maintenance costs cover the operation of the basic 1986 system (bus system or rail system supported by feeder buses) plus the operation of the required fleet expansion to accommodate the projected future transit ridership between 1986 and 2001.

Based on available HSR statistics, O&M costs for both conventional and rapid transit systems are assumed to increase at 10 percent per year.

Unit O&M costs per vehicle for both the ICTS and CLRV systems were provided by the Urban Transportation Development Corporation. These were inflated at 10 percent per annum and applied to the projected fleet in operation during each year, 1986 - 2001.

Unit O&M costs (per kilometre) for the bus systems were obtained from HSR statistics. These were inflated at 10 percent per annum and applied to the projected total system vehicle-kilometres operated per year, 1986 - 2001.

These costs are discounted using an interest rate of 15 percent per annum and are expressed in 1981 dollars.

Presented in Table 5.3 are the 1986 and year 2000 operating and maintenance costs by system (discounted to the present and expressed in 1981 dollars).

All costs are total costs. Applicable subsidies will reduce the actual cost to be borne by the Municipality.

Although considerable efforts were expended to ensure the reliability of the cost estimates, it should be noted that the costs represent "orders of magnitude" for the express purpose of comparing the defined alternative nodes.

Table 5.2

Costs - Summary
1981 Dollars ($ Million)

	ICTS Elevated	ICTS Subway	CLRV S-E ROW	CLRV Mixed TR	Conv. Bus	Artic. Bus	Trolley Bus	Priority Lanes
Capital Costs								
o Basic System (1986 Fleet)								
Rapid Transit Line	111.0	230.0	137.0	137.0	-	-	7.0(1)	-
Buses	13.5	13.5	13.5	13.5	17.0	17.0	17.0	16.0
Sub-Total	124.5	243.5	150.5	150.5	17.0	17.0	24.0	16.0
o Additional Requirements 1986 - 2001								
Rapid Transit Line	6.0	6.0	4.5	5.5	-	-	-	-
Buses	4.5	4.5	4.5	4.5	7.0	7.0	7.5	6.5
Sub-Total	10.5	10.5	9.0	10.0	7.0	7.0	7.5	6.5
o Total System Requirements to 2001								
Rapid Transit Line	117.0	236.0	141.5	142.5	-	-	7.0	-
Buses	18.0	18.0	18.0	18.0	24.0	24.0	24.5	22.5
Total Capital Cost	135.0	254.0	159.5	160.5	24.0	24.0	31.5	22.5
O & M Costs								
o Basic System (1986 Fleet)								
Rapid Transit Line	25.5	28.5	45.5	44.0	-	-	-	-
Buses	80.5	80.5	80.5	80.5	99.5	93.5	96.5	95.5
Sub-Total	106.0	109.0	126.0	124.5	99.5	93.5	96.5	95.5
o Additional Requirements 1986 - 2001								
Rapid Transit Line	1.5	1.5	6.0	7.0	-	-	-	-
Buses	16.0	16.0	16.0	16.0	24.0	22.0	22.0	23.5
Sub-Total	17.5	17.5	22.0	23.0	24.0	22.0	22.0	23.5
o Total System Requirements to 2001								
Rapid Transit Line	27.0	30.0	51.5	51.0	-	-	-	-
Buses	96.5	96.5	96.5	96.5	123.5	115.5	119.5	119.0
Total - O & M Costs	123.5	126.5	148.0	147.5	123.5	115.5	119.5	119.0
TOTAL COSTS (Capital, Operating and maintenance)	258.5	380.5	307.5	308.0	147.5	139.5	151.0	141.4

(1) Capital cost for electrical distribution system.

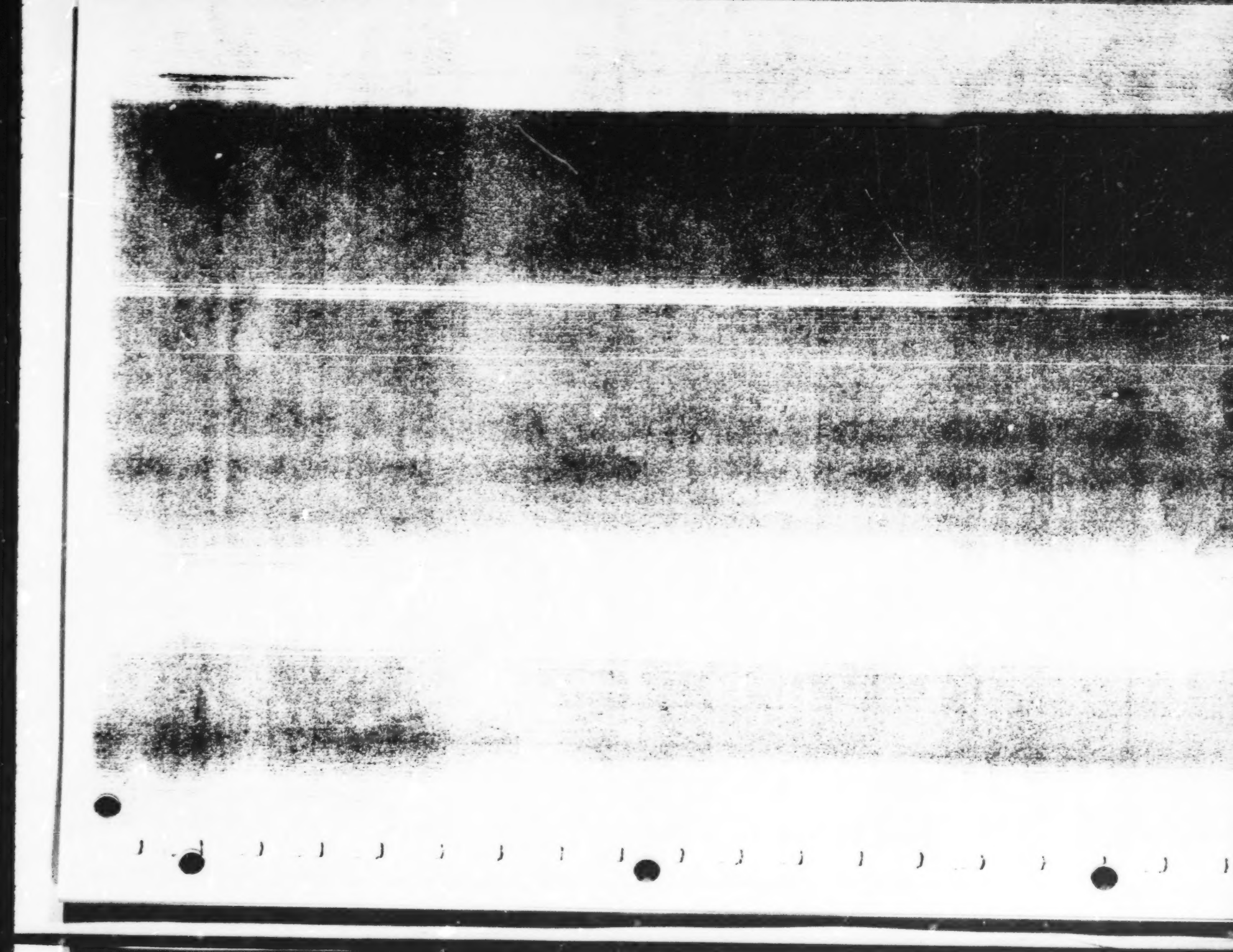
TABLE 5.3

COMPARISON OF REPRESENTATIVE ANNUAL

OPERATING AND MAINTENANCE COSTS

(1981 Dollars - $ Millions)

Year	ICTS Elevated	ICTS Subway	CLRV Semi-Excl. R.O.W.	CLRV Mixed Traffic	Conventional Bus System Expanded	Bus System Expanded With Articulated	Bus System Expanded With Trolleys	Bus Priority Lanes
1986	9.5	9.8	11.3	11.2	8.6	8.1	8.3	8.6
2000	7.3	7.4	8.8	8.9	8.2	7.6	7.8	7.5



6. PERFORMANCE SUMMARY AND EVALUATION

6.1 Performance Summary

A summary of the performance of each alternative in relation to the evaluation criteria grouped under the six major evaluation categories is presented in Table 6.1.

EVALUATION CRITERIA	RAPID TRANSIT				CONVENTIONAL TRANSIT			
	ICTS		CLRV		ON-STREET BUS TRANSIT			
	ELEVATED	SUBWAY	S.E. R.O.W.	MIXED TRAFFIC	CONV. COACH	ARTIC. VEH.	TROLLEY BUS	PRIORITY LANES
3. IMPLEMENTATION								
CONSTRUCTION EFFECTS	Long term disruption for cut and cover.							
	Short section of Upper James only.	Rest of Route.	Short sections of Upper James only.					
	Short term disruption of traffic during construction of columns and placement of precast beams	Long term traffic disruption and partial road closings to accomodate cut and cover construction	Partial road closings required over short term to accommodate construction.		No construction impacts.			
LAND REQUIREMENTS	Air rights and minor widenings at several locations.	No land required.	May require significant additional land to accommodate the exclusive right-of-way below the escarpment.		No land required.			
ROAD ACCESS	Restricts left turns to several properties.	No impact.	Tunnel portals will close Augusta Street and Jackson Street at Hughson Street. Major restrictions on turns, access and cross traffic. Hughson Street closed.	Left turn traffic interferes with transit operations.				
ROAD CAPACITY	No impact.		Little impact if James Street widened at St. Joseph's Hospital.	Reduction in capacity due to passenger loading operations and buses on Jolley Cut.				Major reduction in road capacity due to elimination of one lane.
4. URBAN IMPACTS								
VISUAL IMPACT - MOUNTAIN AREA	Significant impact on views, privacy.		Impact of views, divides street.				Minor impact of overhead wires.	
			Minor impact of overhead wires and tunnel portal.					
VISUAL IMPACT - LOWER CITY AREA	Significant views Hughson and Core area, privacy.		Significant - trackbed at portal, possible fencing - loop impacts Gore Park.				Minor impact of overhead wires.	
	Large structure over streets.		Impact of tunnel portals.					
			Minor impact of overhead wires.					
TRANSIT IMAGE	Very positive Highly visible.	Moderate.	Moderate.	Minimal.				
SUPPORT FOR DEVELOPMENT	Good support around Mountain stations.							
	Good support downtown with two stations.	Centralizes development support.	Centralizes development support.	Minimal support.				
	Supports - Plus 15 pedestrian connections.							

TABLE 6.1

PERFORMANCE SUMMARY

EVALUATION CRITERIA	RAPID TRANSIT			CONVENTIONAL TRANSIT				
	ICTS		CLRV	ON-STREET BUS TRANSIT				
	ELEVATED	SUBWAY	S.E. R.O.W.	MIXED TRAFFIC	CONV. COACH	ARTIC. BUS	TROLLEY BUS	PRIORITY LANES
1. SYSTEM OPERATIONS								
FREQUENCY OF SERVICE	Provide headways of 3.5 minutes or less across the escarpment.			Provide headways ranging between 8 and 20 minutes depending on route.				
TRAVEL TIME	Shortest travel times to/from the downtown for most Mountain residents.			Travel time differences will continue to increase due to traffic delays as road congestion increases.				
TRANSFERS	Most downtown to Mountain passengers would be required to transfer to/from feeder buses.			Most Mountain passengers would not be required to transfer.				
TRAFFIC DELAYS	Independent of traffic.		Independent of traffic except for potential conflicts with cross traffic at several points.	Subject to congestion and potential conflicts at all roadway intersections and to delay caused by other turning vehicles. Increasing future road congestion as existing roads reach capacity and breakdown will have a serious impact on transit.				
				Subject to congestion downtown, but not at escarpment crossing.				
2. SYSTEM DESIGN								
RIDE COMFORT	Sophisticated electronic controls combined with an independent running surface and fewer stops will result in smoother acceleration/deceleration profiles and a comfortable ride		The degree of ride comfort will be limited by the experience and capabilities of the driver and the frequency of designated transit stops on route					
			Subject to interruptions by cross traffic	Subject to random stops due to congestion, cross traffic and turning vehicles				
PASSENGER BOARDING CONVENIENCE	High-level platforms, prepaid fares to speed boarding.		High-level platforms at major stations.	Passengers must climb steps to board vehicles and pay fare on board.				
				Poses potential problem to pedestrians crossing traffic lanes to board transit vehicles.				
	Weather protected, paper free transfers to feeder buses at major stations							
ON-BOARD SECURITY	Attendants in Stations.		Driver on vehicle.					
	Emergency evacuation procedures required throughout entire route. 2 way emergency radio on vehicle.		Emergency evacuation procedures required in tunnel.					
RELIABILITY	Not subject to inclement weather conditions.		Partially subject to inclement weather conditions, particularly in tunnel (traction).	Subject to inclement weather conditions (traction and traffic delays).				
	Electrical systems are subject to power failures.						Subject to power failures.	
	Emergency back-up system provided.							
FLEXIBILITY	Large capital expenditure required to provide the capacity to accommodate projected future increases in demand.			In the short term, small incremental capital expenditures will provide the projected capacity requirements, although with increasing travel times.				

EVALUATION CRITERIA	RAPID TRANSIT				CONVENTIONAL TRANSIT				
	ICTS		CLRV		On-STREET BUS TRANSIT				
	ELEVATED	SUBWAY	S.E. R.O.W.	MIXED TRAFFIC	CONV. COACH	ARTIC. VEH.	TROLLEY BUS	PRIORITY LANES	
SUPPORT PLANNING POLICIES	Good service between Mountain and downtown to encourage transit usage			Slightly improved service crossing the escarpment.	Does not adequately satisfy public policy to encourage transit usage.				
	Two downtown stations support nodes.		Some barrier effect possible.						
5. ENVIRONMENTAL IMPACTS									
NOISE AND VIBRATION	Promises to be quietest vehicle in operation.		Likely to exhibit highest noise levels which are further amplified on curves.		Higher noise levels which are further amplified due to frequent stops and starts.		Quiet.	Higher noise levels which are further amplified due to frequent stops and starts.	
	Vibration impacts cannot be ascertained at this time.								
AIR QUALITY	Electrically operated vehicles do not contribute directly to air pollution and eliminate many diesel buses from downtown area.				Contributes directly to existing air pollution which will increase with more buses in the future.		Does not contribute directly to air pollution.	Contributes to existing air pollution which will increase with more buses in future.	
ENERGY	Similar energy consumption per passenger kilometre at design load.				Highest per passenger kilometre.	Higher per passenger kilometre.			

6.2 Evaluation

The performance of each alternative was assigned a numerical rating between one (1) and three (3). A high score is indicative of a strength of the mode in relation to that particular criteria and the other alternatives; a low score is indicative of a weakness of the mode in relation to that particular criterion and the other alternatives. It should be noted that, although a subtotal has been provided, each category of criteria has been given an equal weight, and therefore, the scores may not be truly additive. The results of this evaluation are shown in Table 6.2.

The results of the evaluation are summarized as follows:

- System Operations: both ICTS modes were assigned the highest overall performance ratings, with CLRV on a semi-exclusive R.O.W. second. The ICTS systems had the best ratings because they provided the shortest travel time and were independent of road traffic delays.

- System Design: the rating was similar to that for system operations, with both ICTS modes rated highest, and CLRV on a semi-exclusive R.O.W. second. The ICTS systems had the best performance because they were reliable, comfortable and were convenient for passengers to board.

- Implementation: the on-street bus systems with conventional coaches only, or with some articulated vehicles, were assigned the highest ratings. Trolley buses were second. The bus systems were given the highest rating because they had no construction impacts or land requirements and did not restrict property access.

- Urban Impacts: the ICTS subway was judged to have the highest rating, followed by ICTS elevated. The ICTS subway system had the best performance because it had fewer visual impacts (it is underground) and supported planning policies.

- Environmental Impacts: the best ratng was assigned to ICTS elevated, followed by ICTS subway, then CLRV on a semi-exclusive R.O.W. The ICTS elevated system had the best rating for environmental impacts because it is quiet, energy efficient and causes no air pollution.

- Cost: the bus systems (excluding trolley) had the lowest cost (combined capital, operating and maintenance), followed by trolley bus, ICTS elevated, CLRV (both modes have similar costs) and ICTS subway, in order of increasing cost.

The evaluation is presented in Table 6.2.

Although the categories of evaluation criteria were all given equal weight, an analysis of the sensitivity of the results to weighting was carried out. A close examination of Table 6.2 shows that the evaluation results are relatively insensitive to weighting. The CLRV scored lower than the ICTS in all categories and, therefore, it is not possible for these alternatives to be ranked higher than the ICTS by differentially weighting the categories. Similarly, the expanded bus systems were judged to perform at a lower level than the ICTS in all categories except implementation. It would be necessary to weight implementation as over seven times more important than any other criteria in order for the expanded bus service to be rated as superior to the ICTS systems. Since such a large weighting on the implementation category would be inconsistant with the remainder of our analysis, we are confident that the overall results of the performance valuation are valid.

TABLE 6.2
EVALUATION OF TRANSIT SYSTEMS

Criteria	Rapid Transit			Conventional Transit				
	ICTS Elevated	ICTS Subway	CLRV Semi-Exclusive Right-of-Way	CLRV Mixed Traffic	Standard Coach	Articulated Bus	Trolley Bus	Priority Lanes
SYSTEM OPERATIONS								
- Frequency of Service	3.0	3.0	3.0	3.0	1.0	1.0	1.0	1.0
- Travel Time	3.0	3.0	2.5	1.0	1.0	1.0	1.0	1.5
- Transfers	1.0	1.0	1.0	1.0	3.0	3.0	3.0	3.0
- Traffic Delays	3.0	3.0	2.5	1.0	1.0	1.0	1.0	1.0
Sub-Total	10.0	10.0	9.0	6.0	6.0	6.0	6.0	6.5
SYSTEM DESIGN								
- Ride Comfort	3.0	3.0	2.0	1.5	1.0	1.0	1.0	1.5
- Boarding Conv.	2.5	2.5	2.5	1.0	2.0	2.0	2.0	2.0
- Security	1.0	1.0	2.0	2.0	3.0	3.0	3.0	3.0
- Reliability	2.5	2.5	2.0	2.0	1.5	1.5	1.5	1.5
- Flexibility	2.0	2.0	2.0	2.0	2.0	2.0	1.5	2.0
Sub-Total	11.0	11.0	10.5	8.5	9.5	9.5	9.0	10.0
IMPLEMENTATION								
- Construction Effects	2.0	0.5	1.0	1.0	3.0	3.0	2.5	3.0
- Land Requirements	2.0	2.5	1.5	2.5	3.0	3.0	3.0	3.0
- Road Access	2.0	3.0	1.0	3.0	3.0	3.0	3.0	3.0
- Road Capacity	3.0	3.0	2.0	1.5	2.0	2.0	2.0	0.5
Sub-Total	9.0	9.0	5.5	8.0	11.0	11.0	10.5	9.5
URBAN IMPACTS								
- Mountain Area	1.5	3.0	2.0	2.5	3.0	3.0	2.5	3.0
- Lower City	1.5	3.0	1.5	2.0	3.0	3.0	2.5	3.0
- Transit Image	3.0	2.5	2.0	1.5	0.5	0.5	0.5	1.0
- Supports Development	3.0	2.5	2.0	1.0	1.0	1.0	1.0	1.0
- Planning Policies	3.0	2.0	1.5	1.5	0.5	0.5	0.5	1.0
Sub-Total	12.0	13.0	9.0	8.5	8.0	8.0	7.0	9.0
ENVIRONMENTAL IMPACTS								
- Noise & Vibration	3.0	2.5	2.0	2.0	1.0	1.0	2.0	1.5
- Air Quality	3.0	3.0	3.0	3.0	1.0	1.0	2.0	1.5
- Energy	3.0	3.0	3.0	3.0	1.0	2.0	1.0	1.5
Sub-Total	9.0	8.5	8.0	8.0	3.0	4.0	5.0	4.5
SUMMARY	% of Total Possible Scores							
- System Operations	83%	83%	75%	50%	50%	50%	50%	54%
- System Design	73%	73%	70%	57%	63%	63%	60%	67%
- Implementation	75%	75%	46%	67%	92%	92%	88%	79%
- Urban	80%	81%	60%	57%	53%	53%	47%	60%
- Environmental Impacts	100%	94%	89%	89%	33%	44%	55%	50%
Average	82%	82%	68%	64%	58%	60%	60%	62%
COSTS (1981 Dollars) (millions)								
- Capital Costs	135.0	254.0	159.5	160.5	24.0	24.0	31.5	22.5
- Operating and Maintenance	123.5	126.5	148.0	147.5	123.5	115.5	119.5	119.0
- Total	$258.5	$380.5	$307.5	$308.0	$147.5	$139.5	$151.0	$141.5